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The Art and Science of MEDICAL RADIOGRAPHY

James A. Morgan, R.T.

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The ART and SCIENCE of MEDICAL RADIOGRAPHY

— by —

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Technical Service
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General Electric Company

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DEDICATED TO

All Those Who Use X-Rays

In Medicine

FOREWORD

It is not difficult to understand that a student, entering a training program in x-ray technology, is confused by the sudden exposure to terminology and ideas, peculiar to the study of x-ray and its application in medical radiography. Many excellent texts are available for the detailed study of this subject; most of these texts, however, seem to assume that the student enters training only after acquiring some basic information on x-ray and its application, and has a fair understanding of the principles of electrical engineering.

This monogram is not intended to replace those texts. Rather, this is prepared to serve as a primer and a work-book in radiography, to pave the way for a detailed study of the subject as explained in one of the more complete texts. One of the problems in preparing a work of this type is the thought, "Where does one stop on this phase of the subject?". No book, no instructor can teach you to be an x-ray technician. Herein are some principles, some fundamental information on the subject of medical radiography, presented in language we believe you can understand.

Be somewhat of an unbeliever during the training period in particular. Faith in the instructor is fine, but neither the instructor, this text or any other text can tell you the multitudinous exceptions to the rule, those variations from normal in radiography. Never pass up an opportunity to do an experiment; don't let "George" do all the difficult examinations. He will be gone someday, and those examinations are the ones that test your ability as a technician. Anybody can produce a good radiograph once, under normal, routine conditions, but it takes a good technician to recognize when conditions have changed from normal, and produce a diagnostic radiograph under those changed conditions. If the information on these pages, supplies a foundation on which you can develop an ability as an x-ray technician, and if it whets your appetite for more knowledge on the subject of radiography, the book has accomplished its purpose. From this basic information, your own initiative and effort will determine how much further you will delve into the subject of x-ray. In a field as active and as changing as medical radiography, you become a poor technician the day you stop being a student. Your usefulness to the patient, the radiologist and yourself diminishes from the day you feel you have sufficient knowledge about the art and science of radiography.

If, to an instructor, this book seems too basic, remember it was prepared for the new student. Instruction in any field of activity cannot be too basic for the beginner in that field. Facts that later will be self-evident or routine knowledge to the senior student and the trained technician are not so to the freshman. Your information to them must be easily intelligible, examples and illustrations must be graphic. If you ground them well in fundamentals, this year's freshman students will do you and your instruction program just honor in the Registry examination and as trained technicians.

Personnel and patient protection against the hazards of x-radiation have not been discussed specifically in this text. It is felt that a subject as important as x-ray protection will be thoroughly discussed on its own merits during the training period.

PREFACE

The invitation to prepare this book offered what appeared to be an ideal opportunity to answer those numerous requests, "Why don't you write this x-ray story the way you tell it?". It took only the first few pages of the initial rough draft to realize that an attempt to put what sounds like a good story into written words is quite an undertaking.

To write about the science of radiography is only to recount what others have written before. The cold, hard rules of a science can be expressed in only one way and the written language seems to deny the use of familiar terms and expressions, acceptable to the spoken language. The art of radiography is not explained in writing or lecture. This art is partially characteristic of the good student and the efficient technician, to be developed by one's self, guided, perhaps, by the suggestions of those who have practiced before.

Projects, such as this, are seldom accomplished without the encouragement and assistance of many people. Lecture notes, accumulated over many years, served as source material for much of this text. Origin of some material and ideas is lost in unremembered history, and it is not always possible to give credit where credit is due. Sincere thanks are expressed to the General Electric Company, X-Ray Department, for permission to use material and illustrations from their numerous publications; to Mr. John B. Thomas, a co-worker in the Technical Service Section, for access to his voluminous notes. My wife, with the viewpoint of the uninitiated student-technician, and Mr. William L. Bloom, patiently reviewed the manuscript and suggested changes; Mrs. Betty Stuner deserves special credit for typing the manuscript; Mr. Don Wollenschlager prepared many of the illustrations. Finally, Mr. Thomas Dugan, Publications Director of the Catholic Hospital Association, took over the many details concerned with publication of the book.

JAMES A. MORGAN, R.T., (A.R.X.T.)

Milwaukee, Wisconsin
1962

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INTRODUCTION

DISCOVERY OF X-RAY

History records the discovery of x-ray on November 9, 1895 by Professor William Conrad Roentgen, University of Wurzburg in Bavaria. Some weeks later, on January 23, 1896, Professor Roentgen officially reported his discovery to the Physical Medical Society of Wurzburg in a paper, modestly titled, "A NEW KIND OF RAY". It is undoubtedly true that many scientists before Roentgen produced x-rays in the course of their experimental work, but it remained for him to discover the presence of this mysterious ray and to investigate its generation and recognize its power to penetrate objects, opaque to visible light.

Roentgen gave his momentous discovery to the world, realizing little personal gain except the many honors and world-wide recognition that came to him. In 1901, Professor Roentgen was awarded the Nobel prize in Physics for his discovery of x-ray. Roentgen died in 1923.

Amidst the confusion of fantastic claims and dire predictions of what would result if human beings were exposed to this new ray, medical men were among the first to recognize the import of Roentgen's discovery and its potential applications in relieving the diseases of man.

BEGINNING OF X-RAY TECHNOLOGICAL PROFESSION

The first x-ray technicians were the medical doctors themselves, who possessed the early crude equipment for producing x-rays, and until the time of the first World War, there were few, if any, technicians as we think of them today. Casualties of the War and their care, served to focus attention on the application of x-ray in medicine. About the same time, radiologists became so busy learning to use x-radiation and interpret radiographs, that out of necessity, they were forced to train assistants to produce the radiograph. So the beginning of the medical x-ray technological profession dates back to about the time of World War I. Indeed, the profession has come a long way since those early days and has established itself as an integral part of a team in the accomplishment of medical radiography. You and your fellow student-technicians will have much to do in determining the future of the profession.

Chapter 1

FUNDAMENTALS OF ELECTRICITY

To the student x-ray technician, electrical phenomena are baffling, to say the least, and may seem incomprehensible at times. Nevertheless, anyone entering the field of medical radiography with the intention of acquiring more than passing proficiency in the work, has need for some fundamental information on the subject of electricity before taking up the study of x-ray generation and the function of equipment for that purpose.

It may be well to remind yourself occasionally that you are not preparing to become an electrical engineer, and that there is much knowledge in several other phases of your training which will be of more practical and almost daily use to you as an x-ray technician. Some very excellent electrical engineers are very poor medical x-ray technicians. So, if your interest or inquisitive nature requires more complete satisfaction on the subject of electricity, make this the object of private study. You want enough knowledge to have an appreciation of what happens when you close the switch of an x-ray generator, and you should know enough to develop a healthy respect for the equipment used in the generation of x-radiation. Perhaps, some definitions, woven into a logical sequence, will suffice for this purpose.

ELECTRON THEORY OF THE STRUCTURE OF MATTER

A foundation for this study is laid in the form of a theory concerning the structure of matter. MATTER — anything which occupies space and has weight — may be gaseous, liquid or solid. MASS — the amount of matter possessed by a body. As matter is broken down into its constituents, the first stage is the molecular stage with its unit — the molecule. The MOLECULE may be defined as the smallest part of an element or compound still having the characteristic properties of that element or compound. A molecule may be simple — containing two or more like atoms, or compound — containing two or more unlike atoms. The ATOM, then, as a constituent of the molecule is — the smallest divided part of matter that can enter into combination with or chemical reaction with another element. In the electron theory of the structure of matter, the atom is composed of electrons, protons, and neutrons.

What is the electron? The ELECTRON is one of the fundamental building blocks of all matter, and is defined as — the smallest measurable quantity of negative electricity.

What is the proton? The PROTON is another fundamental building block of all matter, about 1800 times heavier than an electron, thereby giving an atom some weight, and is defined as the smallest measurable quantity of positive electricity. The magnitude of a positive charge on a proton is the same as the negative charge on an electron — the two particles differ only in the sign of electrical charge.

What is the neutron? The NEUTRON is considered to be an electrically neutral part of an atom, neutral because its positive (proton) and negative (electron) charges conteract each other.

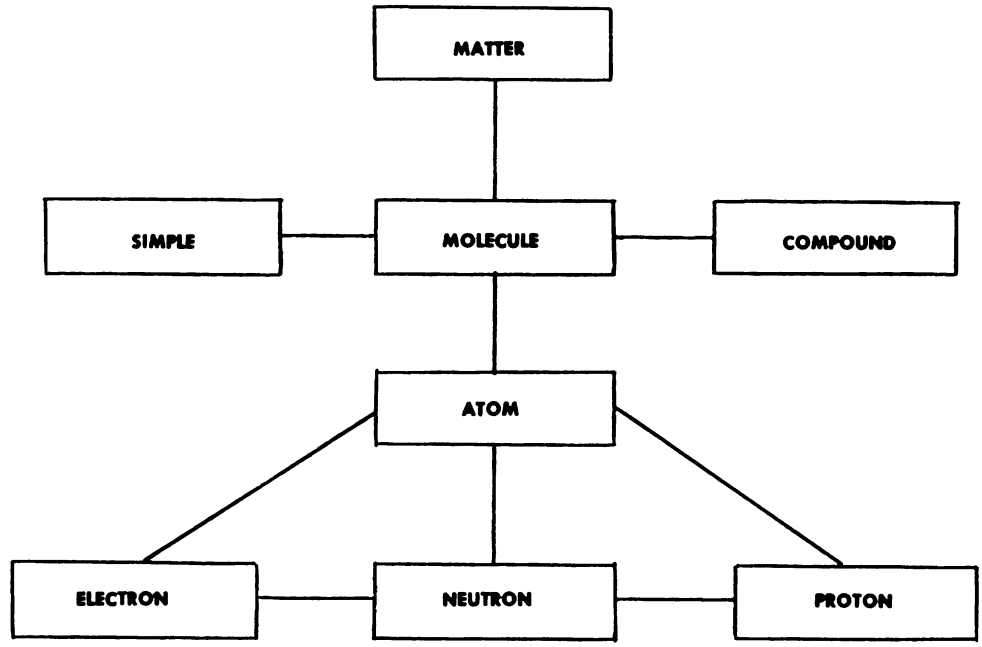
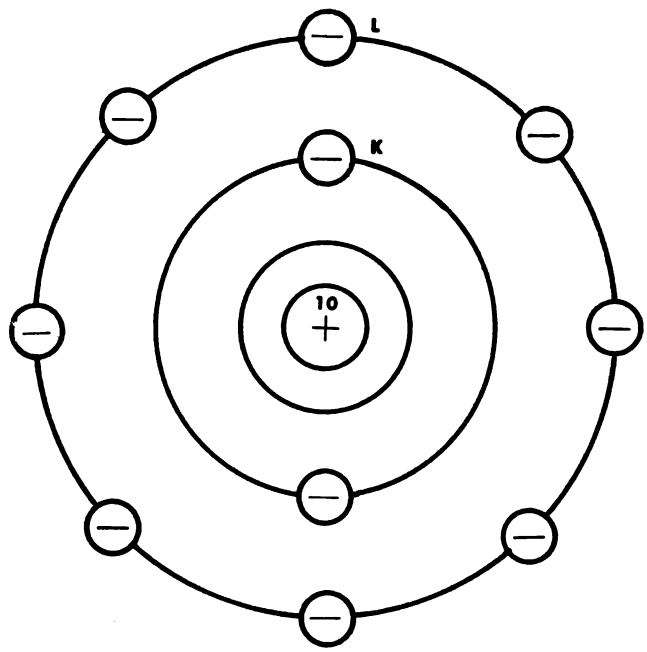


FIGURE 1. — STRUCTURE OF MATTER

Customarily, the atom is pictured as a small solar system, in which the electrons (earth and planets) move about the nucleus (sun) in defined systems and orbits. The negative electrons are attracted to the positive nucleus, but at the same time an equally strong centrifugal force repels these electrons from the nucleus, so that in a stable atom, the balance between attractive and repellant forces results in electrical neutrality.



Two electron paths (K and L) around nucleus of atom, after Niels Bohr theory of atomic structure. 'K' orbit must have only two electrons. 'L' orbit must have only eight electrons. Number of other orbits and number of electrons in other orbits will depend on place of an atom in the Periodic Table of Atoms.

FIGURE 2. — THE ATOM

Outside forces, such as heat or pressure may be applied to the atom, resulting in some electrons being moved out of orbit, and perhaps, out of the specific atom completely, thus creating an imbalance. However, because the natural tendency of an atom is electrical neutrality, other electrons are immediately attracted to restore and maintain the atom's original stability. This movement of electrons to overcome the imbalance is the basic principle of electricity. Electrons, being negative particles, always flow from negative to positive (like forces repel), but by convention it was decided years ago that current flows from positive to negative.

ELECTRICITY DEFINED

Generally, electricity is referred to as "static" and "current". STATIC electricity is an electric force where the electrons are "static" and cannot flow. This happens when two bodies of matter with unequal charges are near but not in contact with each other. Because of the unequal charges there is an electric attraction, attempting to re-establish equality, but since the bodies are not in contact, current cannot flow. CURRENT electricity is defined as the movement or flow of electrons along a conductor. This conductor will be a type of material, such as copper wire, that permits the free movement of electrons, as distinguished from an insulator, such as glass or porcelain, which prohibits or impedes the movement of electrons. Since electricity is not perceived by the senses, it is difficult to do more than give a simple definition of it. However, we can determine the presence of electricity by some recognizable reactions and we attribute certain effects to its presence. Electricity is often described as a medium for the transmission of energy.

ELECTRICAL TERMS

In the x-ray technician's language certain electrical terms are commonplace. These, at least, should be known:

AMPERE — The rate at which electrons move through a conductor is determined in terms of the ampere, which is a quantitative term, and is defined as — the number of electrons passing a given point in a circuit per second. Just for interest sake, the number is slightly more than six thousand, million, billion per second.

MILLIAMPERE — A measure of quantity one thousand times smaller than ampere. In the generation of x-ray, a relatively small amount of current is used, so the term, milliampere, is more familiar to the technician.

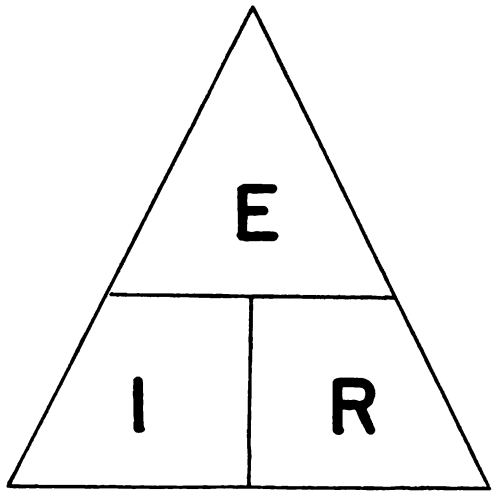
VOLT — In measuring current electricity, two factors must be considered, (a) the number of electrons (amperage); (b) the pressure which causes these electrons to move (voltage). The volt, then, is the unit of pressure. If the pressure is low, only few electrons will flow; if pressure is great, more electrons flow.

KILOVOLT — A measure of pressure one thousand times more than the volt. In the generation of x-ray, high voltages are used, so the term, kilovolt, is more familiar to the technician.

WATT — is the unit of power and signifies the power used when one volt causes one ampere of current to flow. Simply, volume and pressure, in combination, produce power and electrical power is the rate of using electric energy as measured in terms of the watt. Amperes $\times$ Volts = Watts.

RESISTANCE — is that property of a circuit which acts as a hindrance to the flow of electricity.

OHM — A measurement of resistance, and is the amount of resistance which permits one ampere of current to flow under the pressure of one volt in a circuit. Ohm's Law states that current is directly proportional to voltage and inversely proportional to the resistance. A simplified formula incorporating Ohm's Law is: $E = I \times R$; $I = E \div R$; $R = E \div I$.



To solve for the unknown, cover the unknown and the relationship of the remaining factors indicates a means of establishing the unknown value, where E = volts, I = amperes, R = ohms.

FIGURE 3. — OHM'S LAW TRIANGLE

TYPES OF ELECTRIC CURRENT

There are two types of electric current. One is called "direct current". In direct current, the flow of electrons through a circuit is always in one direction. This is the type of current produced by the familiar dry cell battery. Direct current, as such, is not satisfactory for the operation of an x-ray generator, and would require the use of a rotary converter to change direct current to alternating current before introduction into an x-ray generator.

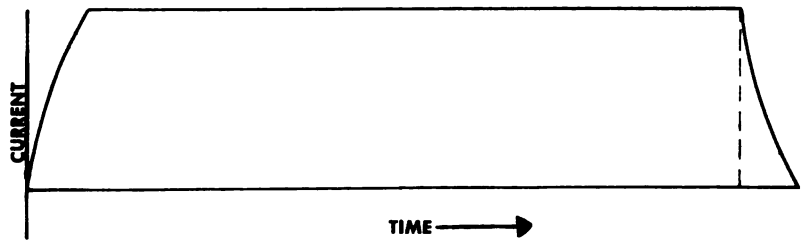


FIGURE 4. — DIRECT CURRENT

Another type is "alternating current". Alternating current is a movement of electrons which rhythmically changes direction from positive to negative and back to positive at regular intervals, and in which there is an increase and decrease in the number of electrons flowing. This change in direction of current flow in an alternating current system may take place from 25 to 60 times per second, depending on the established frequency.

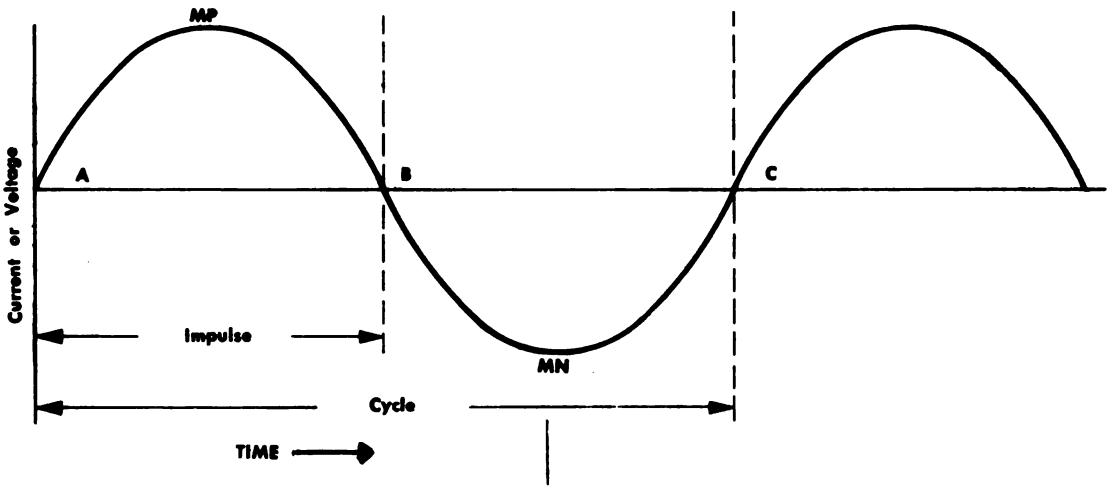


FIGURE 5. — ALTERNATING CURRENT

Voltage starting at zero (A) builds up to a maximum positive value (MP), then down to zero (B), and on to a maximum negative value (MN) and back to zero (C). The time from point (A) to (B) or (B) to (C) is one impulse; (A) to (C) is one cycle or two impulses. Assuming 60 cycle current, the time from (A) to (B) is 1/120 second; from (A) to (C) is 1/60 second, and this change takes place sixty times per second. Since frequency is cycles per second, the frequency of this current is sixty. If you are reading this page by the light of an electric lamp, power to light that lamp is probably furnished by a 60 cycle alternating current — the most common frequency used in this country today.

The action of alternating current during one impulse of current flow is sometimes compared to a flow of water from a faucet as it is opened and closed. When closed, no water flows from the faucet. As it is opened, the volume of water flowing increases until it reaches a maximum when the faucet is wide open. As the faucet is closed, the volume of water gradually decreases until there is no water flowing when the faucet is completely closed. If it takes two seconds to open and close the faucet, the flow of water is increasing to a maximum in one second; then the flow gradually decreases during the next second, and the faucet is closed at the end of two seconds. Whereas the change from zero to maximum to zero consumed two second's time in this example, the change from zero to maximum to zero takes only one-one hundred-twentieth of a second in sixty cycle alternating current.

It is this type of electrical current that is required for operation of an x-ray generator because the generator contains several devices called "transformers", which function only on alternating current.

MAGNETISM

Understanding the operation of a transformer is simplified by a few preliminary words on magnets and magnetism.

Certain natural magnets are known to possess a field of attraction or "field of force" in their vicinity, said field of attraction consisting of lines of magnetic force. The area of this field of attraction will be consistent with the strength of the magnet. The earth itself is a huge natural magnet with a multitude of lines of force extending between centers of magnetic attraction at or near the north and south poles. A principle of magnetism states that, "unlike poles attract and like poles repel", and it is this principle which explains why the magnetized needle of a compass always takes a north-south position.

Certain metals, too, will become magnetized when placed in a magnetic field. Some metals, such as iron, which is easily magnetized, retain little of the magnetism after removal from the field. Steel on the other hand, is much more difficult to magnetize and steel retains the magnetism after removal from the magnetic field.

When an electric current is passed through a piece of wire, a magnetic field is set up around the wire. In this case, the lines of magnetic force surround the wire in concentric circles.

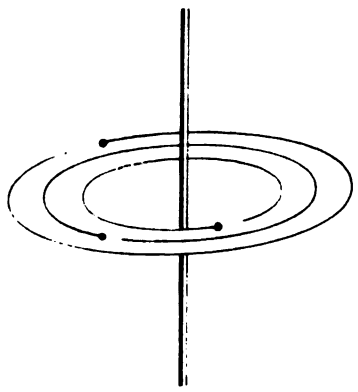


FIGURE 6. — MAGNETIC FIELD AROUND CURRENT-CARRYING WIRE

If the electric wire is wound in a coil around a center of air, the strength of the magnetic field is increased.

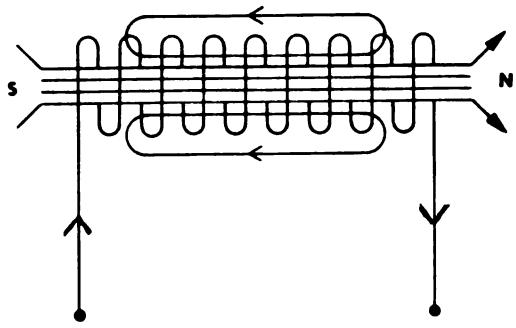


FIGURE 7. —STRENGTH OF MAGNETIC FIELD INCREASED AS WIRE IS WOUND AROUND A CORE OF AIR

Further, if an iron bar replaces the center of air as the core of that wire coil, intensity of the magnetic field is greatly increased because the iron bar becomes magnetized and adds magnetic strength to the original, existing magnetic field.

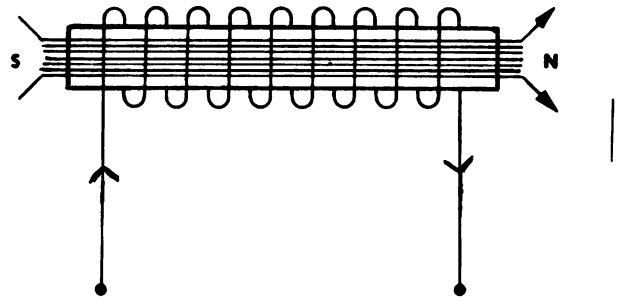
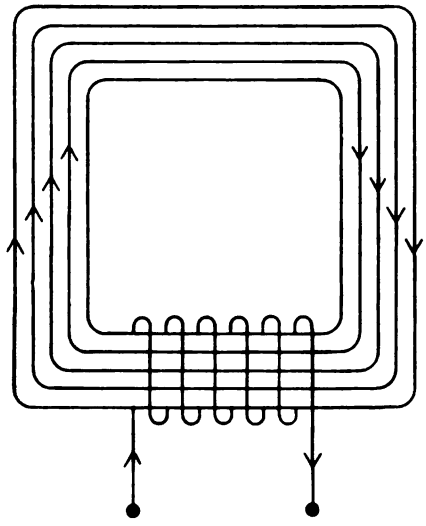


FIGURE 8. — STRENGTH OF MAGNETIC FIELD FURTHER INCREASED AS WIRE IS WOUND AROUND A BAR OF IRON

A further step is to wrap the coil of wire around a closed iron core. The magnetic intensity is greatly increased because the magnetic lines of force within the iron core will now move in a complete circuit through a good magnetic material.



STRENGTH OF MAGNETIC FIELD IS MAXIMUM AS COIL OF WIRE IS WRAPPED AROUND A CLOSED IRON CORE SO THAT LINES OF MAGNETIC FORCE CAN FLOW IN A CLOSED CIRCUIT

FIGURE 9.

ELECTRO-MAGNETIC INDUCTION

In 1831, Faraday discovered that an electric current could be produced in a coil of wire if this wire were placed in a moving magnetic field surrounding another wire coil, even though there was no electrical connection between the two coils. This is called electro-magnetic induction, and is the basis for the operation of a transformer.

REVIEW QUESTIONS

1. Define: MATTER, ELECTRON, ATOM, PROTON, NEUTRON, MOLECULE.
2. Diagram the structure of matter.
3. When pressure has established a state of imbalance in an atom, how does the atom return to original stability?
4. Electron flow is ..... to .....?
   Current flow is ..... to .....?
5. Electricity is
6. Name one good conductor in distinction to a good insulator.
7. Define: AMPERE, VOLT, WATT, MILLIAMPERE, KILOVOLT, OHM.
8. When E = volts, I = amperes, R = ohms, according to Ohm's Law
   Amperage is .....
   Resistance is .....
   Voltage is .....
9. What is alternating current? Define the electrical impulse in 60 cycle alternating current.
10. Draw and label the pertinent parts of a typical "sine" wave of 60 cycle alternating current.
11. What is electro-magnetic induction?

ANSWERS

ANSWERS

ANSWERS

Chapter 2

X-RAY

X-RAY DEFINED

What is x-ray? X-Ray is a form of electro-magnetic radiation, similar to light which has the power to penetrate tissue and can record an image of that tissue on a photographic emulsion. That is not the most scientific definition of x-ray, but it is intelligible, and will serve the purpose, at least, until adequate study dictates the need for a more complicated definition.

PROPERTIES OF X-RAY

What are the properties of x-ray? The properties or characteristics of x-ray are:

1. Invisibility.
2. Physiological action on living tissue.
3. Ionizing action on air (break it into positive and negative ions so that it may become an electrical conductor).
4. Photographic effect on film emulsion.
5. Fluorescent effect on certain crystals (cause these crystals to glow or give off light).
6. Penetrating effect on all forms of matter.

THE ELECTRO-MAGNETIC SPECTRUM

Penetrability of x-rays is a function of wave-length, and it is this characteristic which distinguishes x-ray from other forms of radiant energy. Any beam of light or radiant energy progresses as a wave motion, and the distance between identical points on immediately successive waves is termed "wavelength". Radio waves, infra-red, visible light, ultra-violet, x-rays, gamma rays and cosmic rays — all forms of radiant energy — constitute the electro-magnetic spectrum. Divisions of this spectrum are ascribed to a magnitude of radiant energy as determined by the wave-length of that particular type of radiant energy. Wave length is measured in angstrom units or in meters; an angstrom unit is one hundred-millionth of a centimeter (1/100,000,000 cm.); the meter is 39.37 inches. All forms of radiant energy travel at the same speed, 186,000 miles per second; however, the wavelength of visible light, for example, is shorter than that of infra-red, and wavelengths of x-ray, used in medical radiography, are considerably shorter than those of visible light (about 1/10,000 the wavelength of visible light).

Several other types of electro-magnetic radiation have one or other property of x-radiation, but this property may not be present in a practically usable form, making such radiation unusable for the purpose of medical radiography. It is of academic interest, at least, to know that just beyond and actually overlapping the shortest x-ray wavelengths is another band of wavelengths known as "gamma rays". These, too, could be used in radiography for the same purpose as x-rays, but for several practical reasons they are not used: (a) a source of gamma radiation continually emanates radiation and cannot be turned on and off at will, whereas x-ray production can be started and stopped by human choice; (b) the usual sources of gamma radiation are much more expensive than x-ray generating apparatus; (c) in the light of today's knowledge, the quality and

quantity of x-radiation for medical radiographic purposes is more accurately controllable than gamma radiation. Sources of gamma radiation, however, serve a most useful purpose in the therapeutic application of radiation.

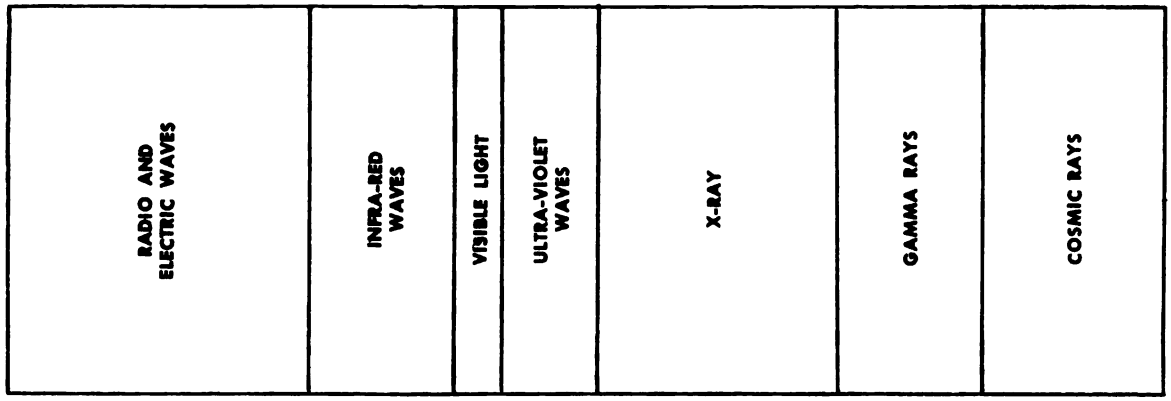


FIGURE 10. — DIVISIONS OF ELECTROMAGNETIC SPECTRUM

GENERATION OF X-RAY

It was previously stated that one of the reasons x-radiation is used in medical radiography is the fact that it can be generated at will, and while the actual production of x-ray is a complicated procedure, not fully understood even today, requirements for the generation of x-rays are rather simple and require only a very elementary-type apparatus.

Three conditions must be present for the generation of x-rays: (1) a source of electrons; (2) electrons must be freed from the source and caused to move at high speed; (3) these rapidly moving electrons must strike some form of matter. So, x-ray will be produced whenever some form of matter is struck by a rapidly-moving, negatively-charged particle, called an "electron".

Whence are those electrons obtained? It is known that electrons are one of the fundamental building blocks of all matter, and therefore, are readily available. One of the most convenient methods to free electrons from a source and make them available for the production of x-ray, is to raise the temperature of the material in which they exist. Raising the temperature of the electron source causes the electron to move faster and faster until some of them are cast off or boiled off from the original source and form an electron cloud in surrounding space. These electrons do not move away from the source unless some force is applied to them.

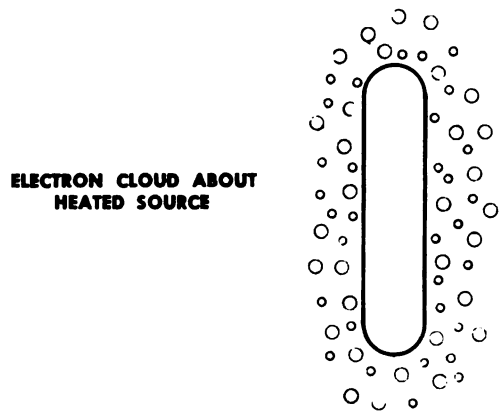


FIGURE 11.

Remember that electrons are negatively-charged bodies, and when two bodies carrying the same kind of electrical charge are brought together, there is a force exerted which repels the bodies from each other. This fundamental idea is used to cause the electrons to move away from their source, the heated material. The source is raised to a high negative potential, and the electrons being negatively charged, move away instead of forming a more or less stationary cloud around the source.

The electrons move away from their source in no designed pattern, even though they are attracted to the target because of the positive potential applied to this target. In order to make efficient use of this energy the electrons are focused into a stream or definite pattern by recessing the source in some type of a reflector. The action of this device is similar to that of the reflector in an automobile headlight which focuses light in a forward direction rather than permitting it to dissipate in all directions.

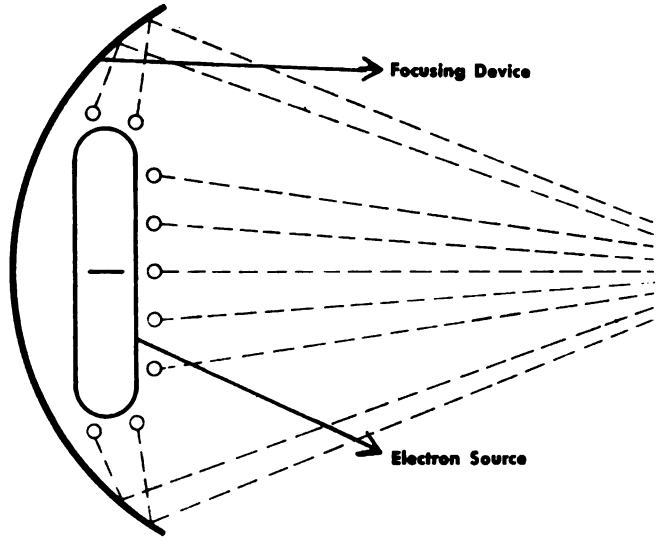


FIGURE 12. — ELECTRON BEAM FORMED BY FOCUSING DEVICE

Having obtained these electrons, set them in motion and formed them into a beam, it is necessary that they strike or bombard something in order to produce x-rays. Remember that x-rays will be produced whenever fast-moving electrons strike some form of matter, whether it be gas, liquid or solid, but again for practical purposes and to make the most efficient use of the tremendous energy in a stream of electrons, they are directed to strike solid matter. The efficiency of x-ray generation is higher for materials having a high atomic number, this automatically dictating the use of heavier metals for the target material. At the moment and point of impact of the electron stream on the target material, x-ray is produced. Just how this is done is not entirely known even today, but it is believed that the bombardment of electrons causes a massive disturbance in the atomic structure of the target material and this, at least in part, results in the production of x-radiation.

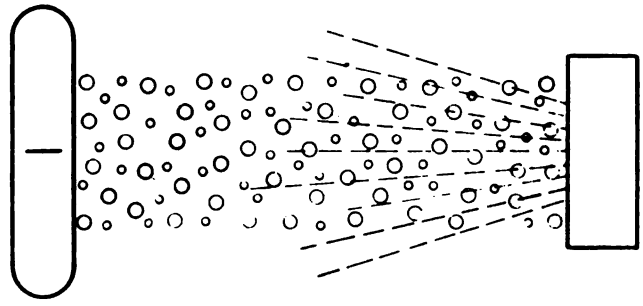


FIGURE 13. — ELECTRON BEAM STRIKES TARGET

Of all the energy contained in the stream of electrons only a very insignificant portion becomes x-ray energy. The Conservation of Energy Law dictates that, "energy can neither be created nor destroyed; it can be changed". Since less than one percent of the electron energy becomes x-ray, the remainder must be transformed into a new kind of energy. Unfortunately, the new form of energy is heat, produced in the target material.

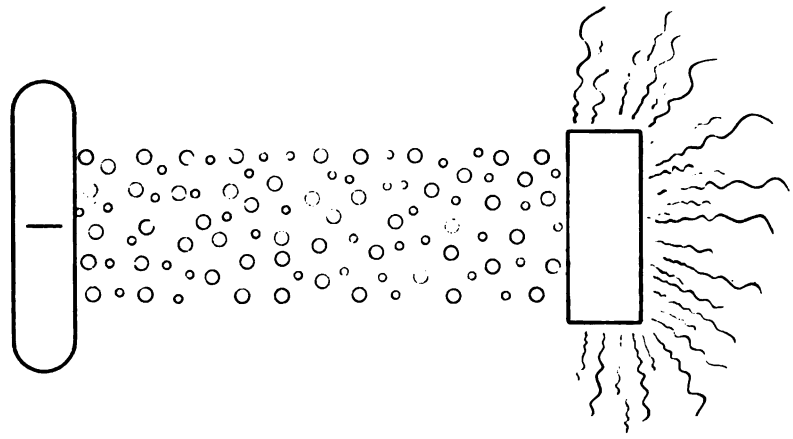


FIGURE 14. — HEAT GENERATED AT TARGET

MEDICAL RADIOGRAPHY DEFINED

What is medical radiography? Medical radiography may be defined as the art of recording on a sensitized emulsion, an image of the inner structures of the human organism. Some may say that radiography is a science rather than an art. Perhaps radiography fulfills the specifications of both, art and science. The actual production of x-radiation and the manipulation of equipment for that purpose is a science, inasmuch as this phase of the work is governed by some well defined rules and principles, but as long as the object to be studied by the application of this x-ray is a human being, variable in many respects from any other human being, you must learn to be an artist. Someday, perhaps, the equipment to accomplish medical radiography will be automated, but behind that automated machine there will be an intelligent person if the application of x-radiation to produce an image of the inner structures of the human organism on a sensitized emulsion is to be successful.

Medical radiography is only one of numerous applications of x-ray. X-radiation is used extensively in the treatment of certain diseases; in such an application, the kilovoltage levels are considerably higher than those used in medical radiography. Kilovoltage employed in therapy applications ranges from one hundred kilovolts for superficial therapy up through one and two million volts for deep therapy.

X-radiation is likewise used in many industrial applications, such as the non-destructive testing of metals, crystal analysis, food sterilization, grain inspection.

TERMS

No one can be associated with the use of x-radiation for long before it becomes obvious that specific terminology is employed to define certain things. Now that we have just defined x-ray and its position in the electro-magnetic spectrum, this is perhaps the time to become familiar with these terminologies, that you may speak as well as listen intelligently to discussions about x-radiation.

These definitions are given in Handbooks 60 and 76, National Bureau of Standards, Recommendations of the National Committee on Radiation Protection and Measurements.

ROENTGEN (phonetically RENT-gen) — (r unit) — "The quantity of X or gamma radiation such that the associated corpuscular emission per 0.001293 gram of air produces, in air, ions carrying 1 esu of quantity of electricity of either sign". This is the international unit of radiation exposure dose or quantity.

The term, 'corpuscular emission', contained in this definition, refers to electrons, liberated by the x or gamma radiation, and these, in turn, produce the ionization. Interpreted, the above definition means that this definite quantity of x-radiation — 1 r — will ionize 1 c.c. of air under standard conditions (0° C. and a pressure of 760 mm. mercury) so that the ions carry one electrostatic unit of positive or negative electricity. Or, stated in another way, the r unit is the amount of x-radiation which will produce one electrostatic unit of charge in 1 c.c. of air, so if we measure the number of electrostatic units in a cubic centimeter of air, that is the number of r.

MILLIROENTGEN (mr) — "A submultiple of the roentgen equal to one-thousandth of a roentgen".

PRIMARY RADIATION — "Radiation coming directly from the target of the x-ray tube. Except for the useful beam, most of this radiation is absorbed in the tube housing".

SECONDARY RADIATION — "Radiation emitted by any matter being irradiated with x-rays".

SCATTERED RADIATION — "Radiation, that during passage through a substance, has been deviated in direction. It may also have been modified by a decrease in energy. It is one form of secondary radiation".

CHARACTERISTIC RADIATION — "Electromagnetic radiation emitted as a result of the rearrangements of the electrons in the inner shells of atoms". It is characteristic of the material from which it arises.

SOFT RADIATION — Radiation of a predominantly long wavelength and little penetrating power. It is produced principally by the use of lower kilovoltage, and becomes available for practical application only as filtration is reduced to a minimum.

HARD RADIATION — Radiation of short wavelength, which has good penetrating power. It results principally from the use of higher kilovoltage and filtration.

LONG WAVE LENGTH RADIATION — Soft radiation.

SHORT WAVE LENGTH RADIATION — Hard radiation.

REVIEW QUESTIONS

1. Define x-ray.
2. What are the characteristics of x-ray? Which are of particular interest in medical radiography?
3. X-rays are, longer — shorter wave-length than gamma rays? Longer — shorter than ultraviolet radiation?
4. What is the electro-magnetic spectrum? How is wavelength of radiation measured? What is wavelength?
5. Why is x-ray particularly suited to the requirements of medical radiography?
6. Three conditions are essential to the production of x-ray. They are:
7. Discuss the theoretical generation of x-ray.
8. What is medical radiography?

ANSWERS

ANSWERS

Chapter 3

PARTS AND FUNCTION OF THE X-RAY GENERATOR

The accomplishment of any art, whether it be photography, cooking or radiography requires the use of certain tools. To the extent that an artist recognizes what the tools can do and becomes proficient in the application of those tools, the artist becomes better-than-average in a selected field of activity.

The modern x-ray unit is a piece of complicated, precision machinery, designed and built to do a job. Learn to respect this tool for what it is; learn to recognize its potential; learn to know how it works, not so much with the thought that you can repair a breakdown, but rather that you may recognize improper function and have remedial steps taken before a total breakdown occurs.

TRANSFORMER CONSTRUCTION

Electric power is generally distributed to the location of an x-ray unit via a 220-240 volt line from the distribution panel located somewhere in the institution. Power of this level is not adequate for the generation of x-rays used in medical radiography, so a very important part of the x-ray unit is a transformer. In fact, the x-ray generator is a good example of the application of different types of transformers, for in an x-ray unit, there are three such devices, each designed to perform a specific function.

To transform means to change, so a transformer may be described as a piece of electrical apparatus consisting of two coils of wire wound around an iron core, but electrically insulated from the core and each other. The purpose of a transformer is to increase or decrease voltage, depending on construction of the transformer. A transformer, whose function is to increase voltage, is known as a step-up transformer; this, in the x-ray unit, is the high-tension or high-voltage transformer. One, whose function is to decrease voltage is called a step-down transformer, and in the x-ray unit such a device is the filament or Coolidge transformer. A third type of transformer, called the auto-transformer, performs either a step-up or step-down function. All transformers, regardless of their function, are dependent for operation on the presence of a magnetic field, and their function is governed by these two principles:

1. When an electric current is passed through a coil of wire, a magnetic field is generated within the coil, the intensity and direction of flow of the magnetic field being dependent on the intensity and direction of current flow and the number of turns of wire.

2. When a magnetic field passes through a coil of wire, voltage will be generated in that coil; the amount of voltage will depend on the strength of the magnetic field, the speed with which the magnetic field cuts through the coil and the number of turns of wire in the coil.

The primary coil of a transformer is the coil attached to the source of electric current, regardless of the type or purpose of the transformer. Principle #1, then, explains the operation of this primary coil. When current is passed through the coil of wire, a magnetic field is set up, to be absorbed and conducted by the iron core. In effect, the iron core becomes a magnet and the magnetic field is proportional to the amount of current applied to the coil. The direction of flow and strength of the magnetic field changes with current changes, and since alternating current is continually changing direction, the magnetic field set up around the coil will be a moving field and change with alternations of the current being applied.

The secondary coil of a transformer is always the load side or the coil from which voltage is taken, regardless of the type or purpose of the transformer. Principle #2 states that voltage is generated in a coil of wire when that coil is transgressed by a moving magnetic field. So, by winding a second coil of wire around the iron core, a voltage will be induced in the second coil as the magnetic field cuts through this coil. If there are more turns of wire in the secondary coil than in the primary, voltage is increased or stepped up; fewer turns of wire in the secondary than in the primary coil means that induced voltage is less than original voltage on the primary side.

TYPES OF TRANSFORMERS

The high-voltage transformer of an x-ray generator is a step-up type of transformer. It increases an input voltage on the primary to some value between 30,000 and 150,000 volts on the secondary, the actual value to be determined by the input voltage.

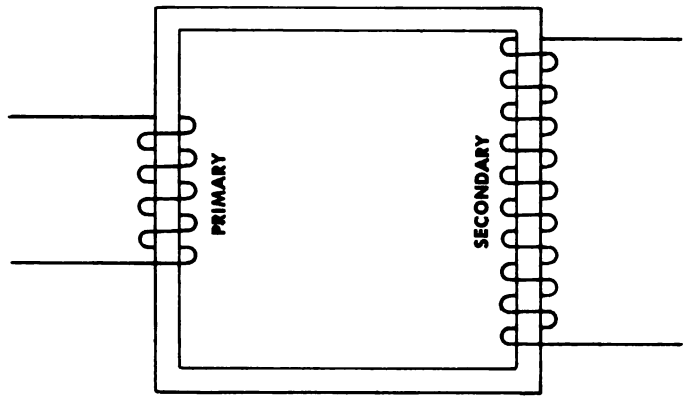


FIGURE 15. — STEP-UP TRANSFORMER

The filament or Coolidge transformer is the step-down type, and decreases an input voltage of the primary to 6—10 volts, sufficient to operate the filaments of the x-ray tube.

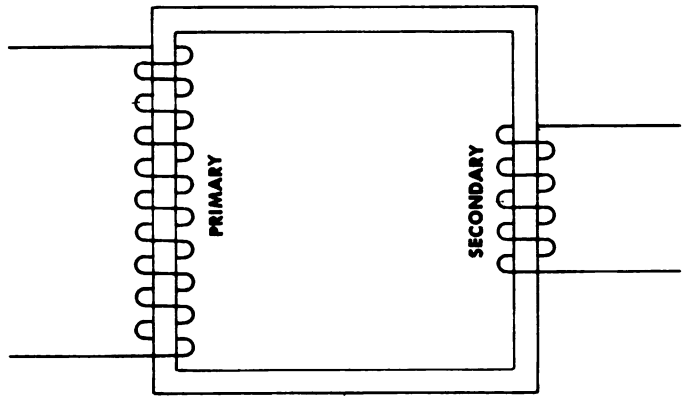


FIGURE 16. — STEP-DOWN TRANSFORMER

The change in voltage between primary and secondary coils is directly proportional to the number of turns of wire in each coil — 100 turns in the primary and 100 turns in the secondary would make for no change in voltage taken from the secondary coil. But, 100 turns in the primary and 5,000 turns in the secondary would make for a secondary voltage fifty times higher than the primary. At the same time the increase in voltage is taking place, there is a proportionate de-

crease in amperage in the secondary coil, and where voltage was increased fifty times in the above example, current in the secondary coil is one-fiftieth of that present in the primary.

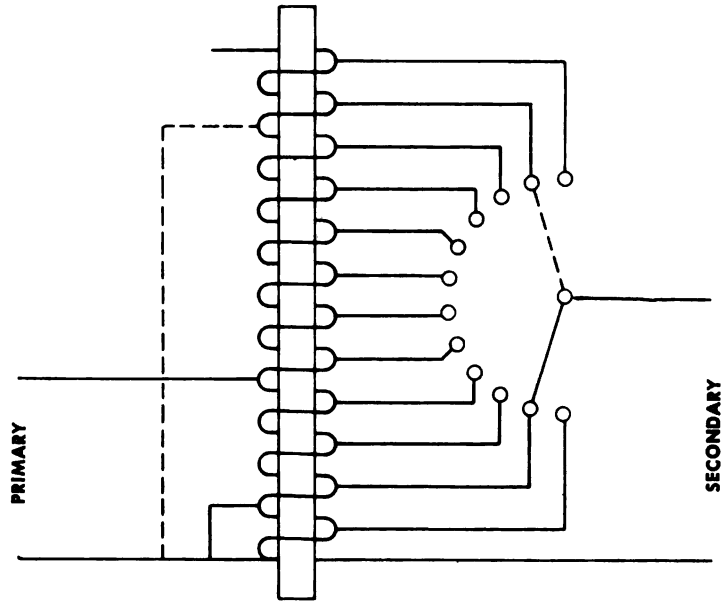


FIGURE 17. — AUTO-TRANSFORMER

In addition to the step-up or high voltage and step-down or filament transformers, an x-ray unit incorporates a third transformer, somewhat different in design than the others, and serving the purpose of either a step-up or step-down transformer. This is called the auto-transformer, and consists of a single coil of wire wrapped around an iron core, part of the coil serving as primary, part serving as the secondary. Perhaps an auto-transformer's function is more easily understood if it is thought of as a voltage-divider. Some total voltage is applied to the primary of the auto-transformer and this total is divisible into pre-determined amounts of voltage in the secondary. These pre-determined amounts are based on the volts-per-turn ratio and this permits selection of some portion of a total voltage for introduction into the high voltage transformer.

Volts-per-turn ratio of the secondary coil of an auto-transformer refers to the number of volts per turn of wire. Knowing this ratio, controls can be furnished so that any desired voltage may be selected by tapping off the proper turns of the coil of wire. In winding the coil, taps or leads are taken off the coil at certain intervals in the winding. Based on an established volts-per-turn ratio, these taps supply specific amounts of the total applied voltage. For example, if a coil of 100 turns of wire, with a tap-off at every tenth turn, has 100 volts applied, the volts-per-turn ratio is 1:1. If the transformer is perfectly efficient, the tenth tap supplies 100 volts. Should only 60 of the total 100 volts be desired, a switch permits selection of the appropriate tap (60th turn of wire) and as long as the volts-per-turn ratio is maintained, 60 volts are obtained.

Fluctuation of the incoming line voltage disturbs the volts-per-turn ratio, and the selected tap in the secondary no longer delivers a desired voltage. To compensate for such fluctuation, a switch is provided in the primary side of the winding, thus supplying a means for maintaining a determined volts-per-turn ratio in the secondary. Assuming that the 100 volts, cited in the previous example, drops to 90 and this amount is applied through the 100 turns of wire, the volts-per-turn ratio is less than 1:1. Consequently, when the 60th tap (60th turn of wire) is selected, something less than 60 volts is obtained. If, however, by a switching arrangement in the primary of the auto-transformer, the 90 volts are applied to 90 turns of wire, then the volts-per-turn ratio is maintained and the 60th tap will deliver the desired 60 volts from the secondary winding. In this manner, an auto-transformer permits application of a consistent input, primary voltage to the high voltage transformer.

While the x-ray transformer changes conventional voltages to quantities adequate for the demands of medical radiography a means must be provided whereby the operator has control of the voltage. This means is provided in the x-ray control. The transformer and control are treated separately for purposes of explanation in this text; customarily, the transformer and control go together as a unit.

REVIEW QUESTIONS

1. What is a transformer?

2. The several types of transformers in an x-ray generator are .....
   ....
   and the function of each is:

3. Upon what two principles do all transformers work?

4. What is the relationship between voltage and amperage in the secondary coil of a step-up transformer?

5. The change in voltage between primary and secondary coil is .....
   ..... to number of turns of wire in the coils.

6. The auto-transformer acts as a .....
   in the x-ray unit. How's that?

ANSWERS

ESSENTIAL CONTROLS OF THE X-RAY UNIT

Even though you may not, at this time, be familiar with the x-ray control, a cursory glance at the control, with its many switches, meters and dials might leave the impression that this is an extremely complex machine to operate. Some of these devices are essential to the controlled production of x-ray; others, while not essential, do add some refinement or make the operation of the unit more efficient. You should become so familiar with the control panel of the x-ray unit that a sketch of the location on the panel as well as the operating range of every meter, dial and switch can be drawn from memory.

Essential Controls

1. The On-Off Switch
2. Filament Control or Milliampere Selector
3. Milliampere-Meter
4. Kilovolt Selector
5. Timer
6. Line Voltage Compensator

Secondary Controls

1. Milliampere-Second Meter
2. Any switch which places an accessory device in or out of the operating circuit.

Now, let us take a look at the essential controls individually, and define the purpose of each.

The On-Off Switch

The purpose of this switch is to energize control circuits of the x-ray unit. There is a long-standing admonition, "Turn Off the X-Ray Control", usually given to student-x-ray technicians early in the training period. The logic of this admonition still holds true, but modern design dictates that we sometimes relax the strictness of this admonition. Some x-ray control cabinets are so designed that, with this switch in the "ON" position, not only are control circuits energized but also filament circuits of the x-ray and valve tubes are energized. It is not good policy to permit the filaments of these tubes to be energized longer than necessary for an exposure. These tubes, like any light bulb, will burn out more quickly as their filaments are lighted unnecessarily.

If the filament of an x-ray tube were energized with the amperage sufficient to produce 300 milliamperes during an exposure, and allowed to remain so for a period of 100 hours it would burn out, even though not one exposure was made during that time. That same filament will produce 300 milliamperes of tube current for thousands of exposures, if it is turned off for an interval between exposures.

Many modern x-ray controls incorporate a so-called "dimming circuit", so that even though these filaments are lighted, they burn only at some low, stand-by amperage, and flash up to full amperage instantaneously before and during an exposure. They revert to the stand-by value at the exposure termination. Such a circuit helps to prolong the filament life of the tubes. Some x-ray control cabinets incorporate push-button selection of milliamperage, and in these, the x-ray and valve tube filaments are not lighted until the milliampere-selector switch makes contact. This type control may be "ON" with no wear on tube filament life. In those controls, which incorporate electronic circuitry, e.g. electronic-type timing, a certain warm-up period is required before electronic tubes in these circuits will pass current, so efficiency requires that these controls be "ON" sufficiently long before an exposure is made, regardless of the wear on tube filaments. However, the ma-selector switch should be returned to the lowest value station when the control is at stand-by so that filaments in x-ray tubes are energized at their lowest value. As a general rule throughout your career, **"Turn Off The X-Ray Control".**

Filament Control or Milliampere Selector

This device, with associated circuitry, is in the low voltage side of the circuit. The purpose of a filament control is to provide the technician with a means of changing the amount of current to the x-ray tube filament, thereby varying or changing filament temperature in the tube. Temperature of the filament determines the number of electrons available for the production of x-ray; as the temperature is increased more electrons are freed from the filament wire, as temperature is decreased, fewer electrons are freed and made available for production of x-ray. In this sense, then, the filament control is a means of varying or changing the quantity of x-radiation produced by the x-ray tube. Since it is not practical to use the same amount of x-ray in all medical radiography, such a control becomes essential. In one instance, a technician may use ten milliamperes of current, this indicating that, either a large quantity of x-radiation is not needed, or a small quantity will be used for a long time. The next radiographic exposure may be a type that requires three hundred milliamperes. To produce this quantity of x-radiation requires a considerable increase in filament temperature and the means for making this change is the filament control.

In equipment of older design, and in some low-power x-ray units today, a manually-operated control, in the form of a rheostat, is available for varying filament current. In this case, the technician is immediately responsible for setting the current at such a value to provide proper filament temperature to assure correct milliamperage or quantity of x-ray during an exposure. Such a manual-type control has the advantage that incorrect setting of filament current can be rectified during an exposure.

The advent of higher capacity equipment and a greater tendency to rapid exposure techniques using high milliamperage dictated the necessity for accurate setting of filament temperature and the desirability of some method of pre-selecting or pre-setting proper filament temperature. The modern, high capacity x-ray unit incorporates push-buttons or some such semi-automatic selection of milliamperage with accompanying selection of proper filament temperature to produce the desired milliamperage. The end is the same, only the means for accomplishing the end has been changed. Now selector switches cut in or cut out resistance in the filament circuit to change the amount of filament current.

Incorporated with the milliampere-selector circuitry is the automated selection of proper filament and focal spot for the milliampere value selected. When a lower value of milliamperage is selected, usually up to one hundred milliamperes, the small filament of a double-filament tube is energized; milliampere selections above one hundred are accompanied by automatic selection of a large filament and focal spot. Without such automated selection of proper filament, a toggle switch is provided and the technician must assume responsibility for seeing that the filament and focal spot used will withstand the exposure energy used.

Milliampere Meter

This meter operates in the high voltage side of the circuit only during the actual production of x-ray. The purpose of the milliampere meter is to indicate the quantity of x-radiation being produced at some filament temperature. Actually, the milliampere-meter measures the amount of current flowing across the x-ray tube during the production of x-ray, and thus serves to indicate the rate of x-ray production. If this meter reads a low value during exposure, e.g., "10", this is an indication that x-ray is being produced in a small quantity, whereas an indication of "200", "300" or higher means that x-radiation is being produced in large quantity.

It would be difficult to say that any one of the essential controls is more important than the others, but certainly from the technician's viewpoint, this milliampere-meter is a highly important component in the control. Very early in your career, it will be well to learn that you should not make an x-ray exposure without watching this milliampere-meter, or at least, glancing at it during the exposure to assure that the x-ray unit is operating properly and that an exposure current is all it needs to be for a desired result.

It may be proper at this point, while describing the milliampere-meter, to recount several more common instances where evidence of faulty equipment operation is gained from observing behaviour of the milliampere-meter during an exposure. The behaviour of this meter could indicate that a film has been improperly exposed, even before it is processed and in this way, save the time and effort involved in darkroom procedure when nothing good will come of the effort.

a. — If the indicating needle does not leave zero point on the meter scale, no current has passed through the tube, and for this reason, no x-ray has been produced, and hence, any attempt to process the film is a waste of time and material.

It must be stated that there is one condition in which x-ray is produced even though the milliampere-meter does not indicate the passage of any current across the x-ray tube. This is a very rare condition, so rare you may never see it happen in the lifetime of an x-ray control, but if the meter rectifying tube is burned out and this circuit is not functioning, the milliampere meter would not indicate the passage of current across the tube but x-ray would be produced when the exposure switch is closed.

b. — One of the earliest indications of malfunction of a valve tube in the current rectifying system is shown on the milliampere meter during exposure. If this meter indicates approximately half the value expected and pre-set, it is quite probable that one or more of the valve tubes is burned out or malfunctioning. In this case, current flowing across the x-ray tube during exposure is reduced to about half value, and only about half the expected film density is obtained, because such a condition reduces the efficiency of a full-wave generator approximately to the level of a self-rectified generator.

A question sometimes arises as to whether or not a full-wave x-ray generator may be operated when one valve tube is non-functioning. The entire onus of responsibility for operating a four-valve, full wave generator under that condition, rests on the technician. In a four-valve circuit, the valves work in pairs to pass the full current wave in correct polarity through the x-ray tube; if one in a pair of valve tubes is non-functioning, its mate is also non-functioning. In such a case, the x-ray tube must suppress the non-productive half-cycle of current, and obviously since current is flowing only during a half-cycle, there is half the desired x-radiation and half density on the film. Increasing milliamperage or doubling time of exposure might approximate correct density on the film, but the x-ray tube might also be damaged in the process. Part of the protection of the x-ray tube has been taken away, so the answer is "No, it is not safe to operate a full-wave x-ray generator when a valve tube is non-functioning". It is much less expensive to replace the valve tube than the x-ray tube.

c. — If during an exposure, the indicating needle of the milliampere meter never quite settles down to a specific point on the meter scale, this may be an indication that the x-ray tube is probably gassy. Such a condition interferes with the passage of current across the tube and hence, the production of x-ray.

d. — If the indicating needle flies across the scale, completely beyond range of the scale, when the exposure switch is closed, this is an indication of a short circuit in the filament circuit. There could be a burned out x-ray tube or high voltage cable, but in any event, there has been an instantaneous burst of high current across the x-ray tube.

Kilovolt Selector

The purpose of the kilovolt selector is to provide a means whereby the technician can change the penetrating power of the x-ray beam. In any combination of technical factors used in medical

radiography, kilovoltage (penetrating power) is selected to provide the quality or kind of x-radiation necessary to penetrate an average amount of normal tissue in any body part. The day's volume of work in a general x-ray department may range from a radiograph of the finger to a lateral view of the lumbo-sacral joint, and obviously, the same quality of x-radiation will not be selected for such widely diverse objects. Then there must be a ready means of varying the penetrating power of the x-radiation to accommodate the opacity of different body parts; this is accomplished by manipulation of the kilovolt selector switch. When this switch is changed, certain taps or leads on the secondary portion of the auto-transformer are selected to provide a desired amount of voltage for introduction into the primary coil of a high voltage transformer. Values indicated on the kilovolt selector dials or meter are assumed to be the actual kilovolts impressed on the x-ray tube during an exposure.

Timer

In order to limit or control x-ray production, some method of timing the interval during which high voltage is applied to the x-ray tube is essential. The milliampere-meter indicates the quantity of x-radiation and the kilovolt selector tells how penetrating x-radiation is, but in order to produce a desirable end result, and of even more concern, to be able to reproduce that end result, it is necessary to introduce and measure the element of time. Therefore, some kind of timing device is essential on every x-ray control, the type and accuracy being somewhat dependent on the capacity of the generator and the type of application to which it is put.

Practically all timing devices of mechanical design, such as the hand timer, the synchronous-motor-driven timer and the mechanical impulse timer, considered conventional until recently, have now become obsolete in favor of electronic type timers. Electronic timers have several advantages:

a. Accurate, repeated exposures can be made more rapidly than with mechanical timers.

b. The shortest timing interval on electronic timers can be shorter than with mechanical timers.

c. Electronic timers are, generally speaking, less subject to breakdown and require less servicing.

Another type of timer, used extensively on x-ray equipment, is the phototimer. There is a basic difference between phototiming and other x-ray timers in that other types measure time and terminate the x-ray exposure at some predetermined time as selected by the technician. A phototimer, on the other hand, measures visible light rather than time. A phototimer functions in this manner — x-radiation passes through the patient recording a latent image of the patient on a film in the cassette. Some x-radiation passes through the cassette and strikes a small flourescent intensifying screen in a light-tight container. A phototube, in that light-tight compartment, views the visible light given off by the fluorescent screen and converts it to electrical energy. This electrical energy is utilized to actuate the main contacter in the x-ray control and to terminate the exposure. Length of exposure is determined by the time required for the phototube to "see enough light" coming from the fluorescent screen and to convert that light energy to electrical energy, so that, the ultimate determining factor in the length of a phototimed exposure is the fluorescence of the intensifying screen as excited by x-radiation which has been transmitted through the patient, film and cassette. The technician is not directly responsible for the duration of a phototimed exposure. The integral parts of a basic phototimer include a fluorescent screen, phototube, capacitor,

switch (in the form of an electronic tube) and a relay to actuate the main contactor. The block diagram illustrates the action of this device.

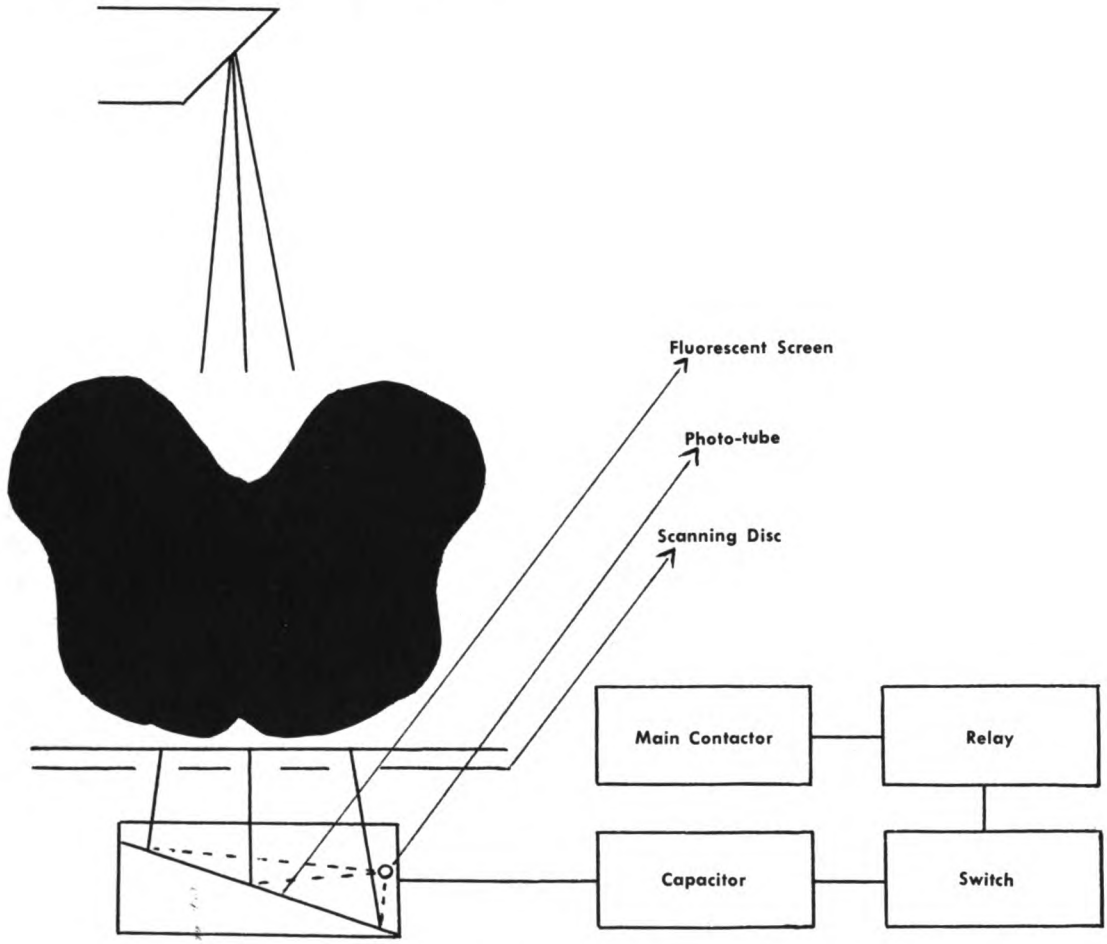


FIGURE 18. — HOW A PHOTOTIMER WORKS

The purpose of the phototimer is to provide the technician with an automatic means of producing proper density on film after film regardless of changes in patient size or opacity. If every patient were the same in all respects, the time of each phototimed exposure would be identical and film density would be the same, since the radiation transmitted to the fluorescent screen would cause it to give off the same quantity of light for each exposure. If, however, as is the case, patients change in size and opacity so that more or less radiation is transmitted to the fluorescent screen in the light-tight box, the quantity of light given off by the screen will change. The phototube will detect this change and terminate or prolong the exposure sufficiently so that original density is maintained.

Incorporated in the circuit of the phototimer is a safety timer whose purpose is to terminate exposure at some maximum time within the safe exposure limits of the x-ray tube. Conceivably, some opaque material between the x-ray tube and phototimer fluorescent screen could prevent the screen from giving off sufficient light and could extend the exposure beyond the time that the x-ray tube would tolerate the exposure, resulting in damage to the x-ray tube. The safety timer will prevent this from happening. Generally, an exposure which has been terminated by the safety timer should be repeated after exposure factors have been corrected to provide a phototimed exposure. The safety timed radiograph may be acceptable, but it would be most unlikely that density of such a film could be duplicated at some future time when the patient would return for a re-examination.

Some intelligence must be exercised by the technician in selecting technical factors for a phototimed exposure. Basically, selection of technical factors is made so that kilovoltage is sufficiently high to provide adequate penetration and milliamperage is of such value that time of exposure will not extend too long nor be so short as to be beneath the minimum time required for the phototimer to operate.

Of great concern in the satisfactory operation of a phototimer is the configuration of the area of radiation transmitted to the fluorescent screen to be converted to visible light. This configuration is controlled by a scanning device in the form of a leaded disc or plate placed between the cassette and the light-tight compartment. If a plate is used, it is mounted in proper position permanently; the lead disc can be rotated so that a single or series of openings are in place, and the remnant radiation, after passage through the patient, film and cassette, passes through these openings to the intensifying screen in the light-tight compartment. Remember that the intensity of fluorescence of this screen is dependent on the x-radiation which strikes it, so that much of the effectiveness of a phototimer in reproducing proper film density depends on the technician's ability and carefulness in accurately positioning the patient so that the area of interest is interposed between the source of x-radiation and the openings in the scanning device.

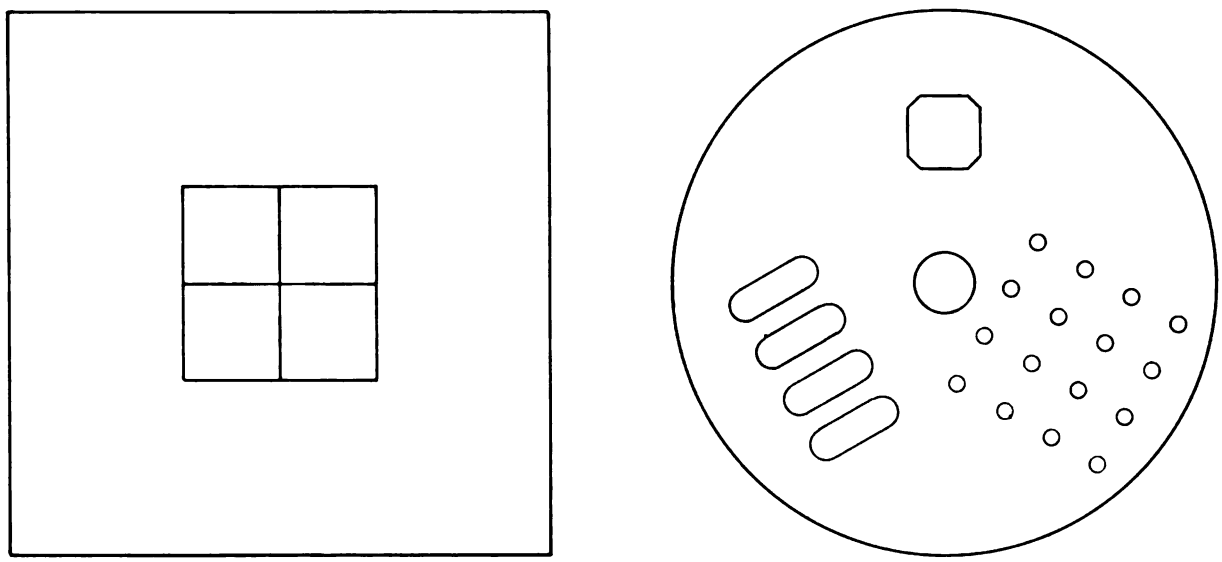


FIGURE 19. — PHOTOTIMER SCANNERS

If bony tissue is of interest in a radiograph, then bony tissue must be placed over the scanning device so that radiation transmitted through bone will pass through the scanner to the fluorescent screen. On the other hand, if density proper for soft tissue is desired, that tissue must be correctly centered over the scanner.

Accurate positioning, then, becomes one of the most important criteria in proper use of the phototimer. The phototimer eliminates the necessity of estimating opacity of tissue and selecting the exposure time to produce proper film density, but in return for this, the technician must place greater emphasis on positioning the area of interest accurately.

Advantages of a phototimer are (a) the capability of duplicating radiographic film density regardless of unknown (unsuspected) changes in tissue opacity; (b) elimination of milliampere-second calculations; (c) elimination of measurement of part; and (d) minimize adjustment of the kilovoltage selector to approximately seven or eight values.

There are two types of phototimers — high speed and standard speed. Circuitry and contacting in the high speed unit are such that exposure times as short as one-thirtieth second may be repeated in a series with no change in density on successively exposed films. A single exposure on such a unit may be successfully timed as rapidly as one-sixtieth of a second. The high speed phototimer is a necessity for chest exposures; it is often used in spot-film phototimers, and may be but is not too often used for phototimed bucky exposures. The standard speed phototimer will permit accurately repeated exposures in a series as short-timed as one-tenth second. Single exposures with this unit are accurate when time is as short as one-thirtieth second. This type phototimer is usually associated with bucky phototimed exposures, and may be used satisfactorily for spot-film applications.

Line Voltage Compensator

Every alternating current source is subject to fluctuations in voltage which may be more or less severe and which may occur at any time. These fluctuations can be detrimental in the operation of x-ray equipment because of the high standards of quality expected in a finished radiograph. To permit a technician to compensate for these fluctuations in line voltage, a line voltage compensator is an essential part of the x-ray control. This compensator adjusts the input voltage to the primary of the auto transformer, so that line fluctuations will not affect the high voltage x-ray transformer and the expected output from that transformer.

Each step of adjustment on a line voltage compensator corrects for the effect of incoming power line fluctuation in the order of about two volts. Failure to make such adjustment prior to an exposure means that all through the high voltage circuit there is a plus or minus value of voltage by the number of steps on the compensator switch necessary to bring the needle on the compensator meter to a zero point. Line fluctuation equivalent to two steps of adjustment on the compensator will be reflected in a change of approximately 40% in film density.

High Voltage Cable

The electrical connection between x-ray transformer and control stand is made by means of insulated and sheathed interconnecting cable. The number of wires in the cable and the number of cables varies with each installation, depending on the type of equipment.

The high voltage connection between the x-ray transformer and x-ray tube is made by means of a pair of special high voltage cables. Each cable must withstand a high voltage test at least equal to one half the maximum kilovoltage rating of the generator since the kilovoltage used is actually divided between the cables under load. The cables will contain the necessary conductors for cathode and anode connections; these conductors are encased in an insulating material, which is then wrapped in a metallic grounding sheath and the entire cable covered with a cotton braid or some other cloth. A prime requisite of the insulating material for these cables is that it have a high dielectric strength so as not to conduct current. The cables must provide flexibility, consistent with their use, but at the same time, not be subjected to sharp bending which could break the insulation and cause a high voltage spark-over under load.

SECONDARY CONTROLS OF THE X-RAY UNIT

These, then, are the essential controls of an x-ray generator, which permit the technician to vary the factors that go to make up an x-ray exposure. Without these essential controls, the technician can not be expected to produce, and surely not to duplicate previously accepted results. In addition to these essential controls, other controls may be present, and while they are not essential

to the production and control of x-radiation, they do compliment essential controls and make for more efficient operation of the equipment. Among these secondary controls is a milliampere second (mas) meter. The purpose of this meter is to measure the x-ray current flow when an exposure time is too short for a milliampere (ma) meter to function accurately. The mas meter usually must be placed into the circuit by the technician during fractional-second exposures by pressing the appropriate switch. Generally, this meter is not considered too accurate when the meter needle swings beyond the midpoint of the meter scale. In many instances, the milliampere and milliampere-second meter are combined into one instrument by putting two scales on the meter face. Normally, the meter serves as a conventional milliampere meter by reading one of the scales, but when a switch is energized, the meter functions differently, and a second number scale is read.

CURRENT RECTIFICATION

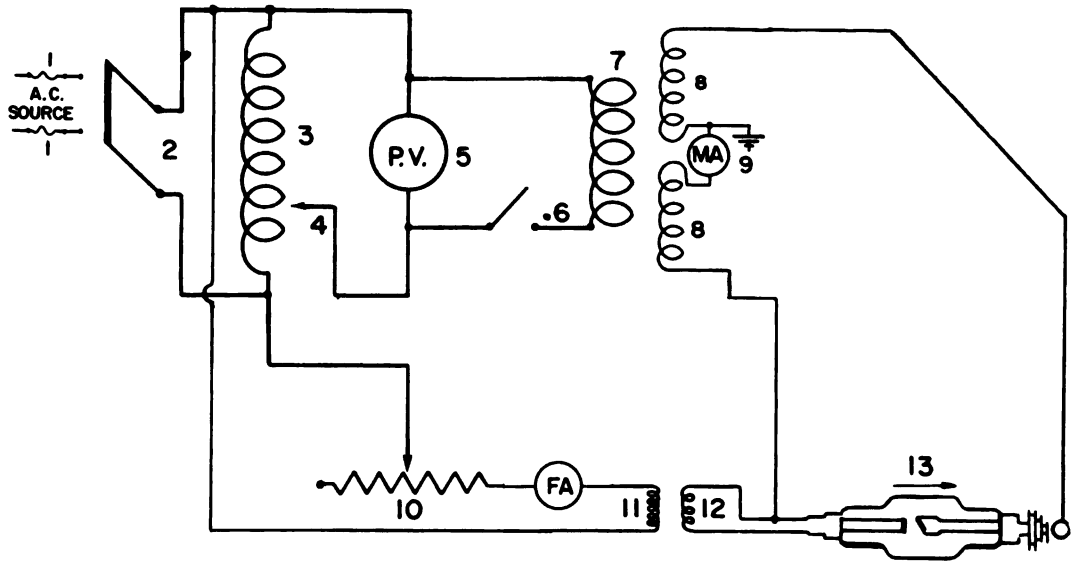
To rectify means to make right. Alternating current is introduced into the primary of the high voltage transformer and alternating current leaves the secondary of this transformer. Since a uni-directional type of alternating current is necessary for proper operation of an x-ray tube, some means must be employed to rectify (change) high voltage alternating current produced by the high voltage transformer to a unidirectional current. In modern x-ray equipment, rectification is accomplished in one of two ways, (1) by the x-ray tube itself; (2) by the use of valve tubes, placed in the circuit between the secondary side of high voltage transformer and the x-ray tube.

SELF-RECTIFICATION

Self-rectification is used in low power equipment such as dental units, some mobile x-ray units and generally limits units to a maximum of 100 milliamperes. The inverse or non-productive half cycle of current is suppressed by the x-ray tube itself and will not pass through the tube under normal conditions. Previously it was pointed out that alternating current continually changes potential — negative to positive and positive to negative and that the cathode end of the x-ray tube must be at a negative potential and the anode end at a positive potential for proper tube function. In self-rectification, the x-ray tube itself permits current to pass only during the half cycle when the cathode is negative and the anode positive. In the next half cycle, when the potentials are reversed the x-ray tube suppresses the flow of current. The tube will continue to function in this manner as long as the x-ray tube anode temperature remains below the point where electrons can be "boiled off" from the metal of the anode. If the anode should become heated to the point of electron emission, then the potential applied in the inverse half cycle will cause these electrons to flow from the anode to cathode, resulting in damage to the filament.

Self-rectification permits the building of compact, light weight x-ray equipment with an initial cost that is usually lower than other types of equipment. However, this type of rectification puts a strain on the x-ray tube and in fact limits all components; tube, transformer and cables.

Rapidly-repeated exposures should not be made with this type of equipment because of the danger of overheating the x-ray tube anode to the point where the anode will emit electrons.



1. Fuses
2. Line Switch
3. Auto-Transformer
4. X-Ray Voltage Control
5. Primary Voltmeter
6. X-Ray Switch
7. X-Ray Transformer Prim.
8. X-Ray Transformer Sec.
9. Grounded Ma. Meter
10. X-Ray Filament Control
11. Filament Transformer Prim.
12. Filament Transformer Sec.

13 X-Ray Tube

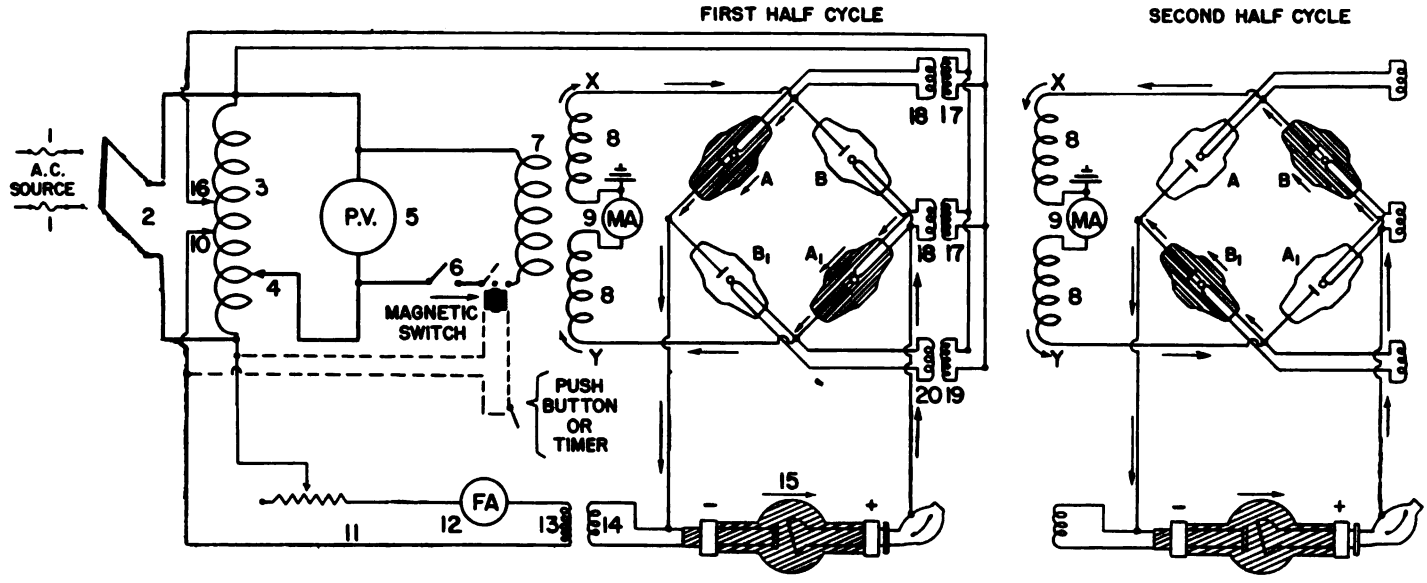
FIGURE 20. — SELF-RECTIFIED CIRCUIT

FULL WAVE RECTIFICATION

Full wave rectification is used in high powered equipment — equipment rated over 100 milliamperes. The alternating current is rectified before it enters the x-ray tube by means of valve tubes. A valve tube is a vacuum tube consisting of a cathode and anode structure, sealed in a glass bulb, similar to an x-ray tube. The valve tube differs from the x-ray tube in manner of operation. The former requires a relatively low voltage to pass current through the tube, while the latter operates with relatively low current and high voltage. The purpose of the valve tubes in a full wave rectified x-ray circuit is to rectify the inverse half cycle of current to the proper polarity so that both half cycles become productive and can be passed through the x-ray tube.

Full wave rectification utilizes four valve tubes, operating in pairs in the circuit, so that efficient use can be made of the complete cycle of alternating current. A pair of valve tubes passes current during the half cycle when the x-ray tube cathode normally would be negative and the anode positive; then a second pair of valve tubes, standing by during the first half cycle, become active and rectify the otherwise non-productive half cycle to the proper polarity to be passed through the x-ray tube.

Full wave rectification permits the tube, cables, and transformers to be operated at a higher rated capacity than these same components can be operated in a self-rectified unit.



1. Fuses
2. Line Switch
3. Auto Transformer
4. X-Ray Voltage Control
5. Primary Voltmeter
6. X-Ray Switch
7. X-Ray Transformer Primary
8. X-Ray Transformer Secondary
9. Grounded Ma-meter (A.C.)
10. X-Ray Filament Voltage Adjuster
11. X-Ray Filament Control
12. Filament Ammeter
13. X-Ray Filament Trans. Primary
14. X-Ray Filament Trans. Secondary
15. X-Ray Tube
16. Valve Tube Filament Adjuster
17. Valve Tube Filament Transformer Primary
18. Valve Tube Filament Transformer Secondary

A-A_1, B-B_1, — Valve Tubes

FIGURE 21. — FOUR VALVE FULL-WAVE RECTIFIED CIRCUIT

REVIEW QUESTIONS

1. What are the minimum controls necessary for efficient control of x-ray production?
2. What is the fallacy of the instruction, "You can turn on the x-ray control and leave it on all day"?
3. Discuss the purpose of filament control or milliampere selector.
4. The filament circuit is in (low) (high) voltage portion of circuit?
5. Discuss several indications of improper functioning of x-ray unit as indicated by behaviour of milliampere meter during exposure.
6. What is the purpose of a kilovolt selector? How does it work?
7. The timer serves what purpose in radiographic exposures? What are the advantages of electronic timing devices?
8. What is the basic difference between a phototimer and other types of x-ray timers?
9. Basic components of a phototimer are:
10. How should exposure factors be varied when the safety timer has terminated a phototimed exposure?
11. The instrinsic value of the phototimer is:
12. What is the scanning disc? Its purpose?
13. Why is patient positioning so critical when the phototimer is used?
14. Advantages of a phototimer are:
15. Could the phototimer be used in direct exposures (no screen) of extremities? Why?
16. What is the purpose of the milliampere meter in an x-ray control?
17. What is the line voltage compensator? What is its importance in proper operation of the equipment?
18. What is the influence on film quality resulting from failure to adjust the line voltage compensator?
19. What is the purpose of the milliampere-second meter? Is it important to know this?
20. Sketch the control of your x-ray unit and identify the meters, switches and other controls.

ANSWERS

ANSWERS

ANSWERS

Chapter 4

THE X-RAY TUBE - CONSTRUCTION AND FUNCTION

The conditions under which x-ray can be produced and the theoretical generation of the x-rays have been discussed in a previous section. Electrical generating and control equipment have been discussed. The x-ray tube, often called the heart of an x-ray unit, is the instrument wherein the theory of x-ray production and the conditions necessary for x-ray generation are applied practically.

COMPONENT PARTS OF THE X-RAY TUBE

The x-ray tube consists essentially of three parts: a cathode structure, the negative terminal or electrode; an anode, the positive terminal or electrode and a glass bulb.

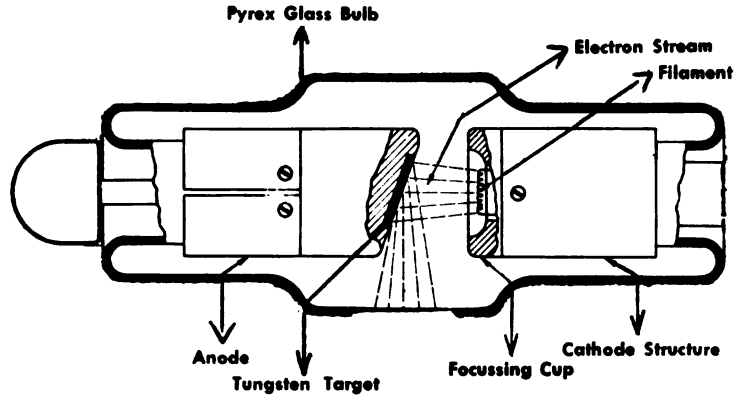


FIGURE 22. — CROSS-SECTION OF X-RAY TUBE

Cathode Structure

The source of electrons in an x-ray tube is the cathode structure containing a spiral of tungsten filament wire recessed in and supported by a focussing cup. Electrical current applied to the filament wire heats it to a high temperature in much the same manner as the filament wire in an electric light bulb. The heated filament "boils off" electrons around and along its length. So that these electrons may be guided in a direction useful for the bombardment of the target the filament is placed in a focussing cup or reflector. Molybdenum is usually the metal used in construction of the focussing cup. The size and shape of the filament and its focussing cup help to determine the size and shape of the area that will be bombarded on the target material of the x-ray tube.

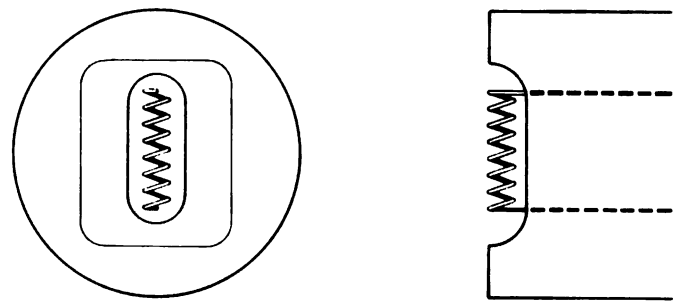


FIGURE 23. — CATHODE STRUCTURE OF X-RAY TUBE

Anode Structure

The structure designed to receive the electrons from the cathode is known as the anode. This structure consists of the target material plus associated heat dissipating parts and other portions as will be discussed. When it is at a positive potential, the anode structure attracts electrons from the cathode to its target.

In x-ray tubes used for medical radiography, the target upon which the stream of electrons will impinge is tungsten. This material is used because it is relatively efficient in the production of x-ray and will withstand a very high temperature before melting. Likewise, tungsten is fairly easy to obtain and lends itself well to the manufacturing requirements in x-ray tube production.

There are two types of anodes in modern diagnostic x-ray tubes; stationary and rotating type anodes. In the stationary anode, the tungsten target is imbedded in a large, solid block of copper. While tungsten has a high melting point it is a poor heat dissipator. Copper, on the other hand, has a relatively low melting point but is an efficient heat conductor. Thus the heat generated in the tungsten is conducted to the copper and the copper is extended through the glass wall of the tube to the oil around the tube and then dissipated through the tube casing into the air. The anode structure is the positive end of the x-ray tube.

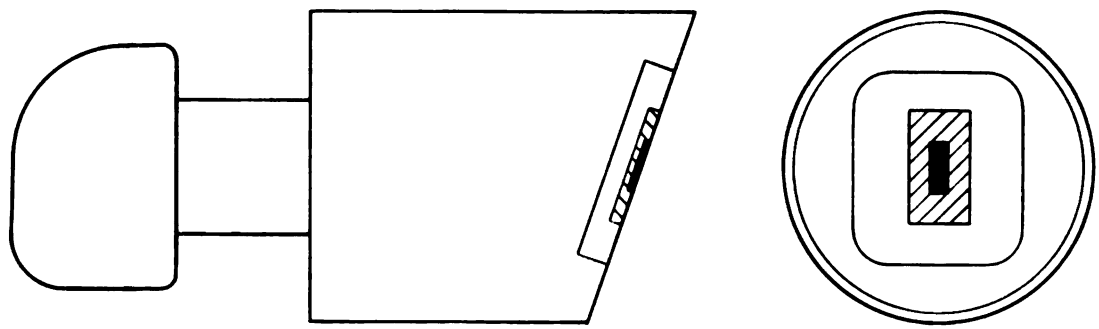


FIGURE 24. — STATIONARY ANODE STRUCTURE

About 1938, x-ray technique had developed to the point that the stationary anode type of tube was not entirely capable of withstanding the temperatures generated by the high energy exposures required in the practice of radiography. Progressive requirements of radiography brought about development of a new tube with a round anode structure which rotates so that comparatively cool tungsten is continuously moved into the area of electron bombardment. This anode is caused to rotate by motor windings external to the tube and the anode itself is the armature or rotor of the motor assembly. This is a special induction motor. Such an anode structure makes possible the use of a small area of bombardment on the target even though exposures are repeated rapidly or a single exposure of high energy is used. Rapid rotation of the target (about 3500 rpm) dis-

tributes heat generated during exposure over a large tungsten area rather than concentrating it in the same small area as is done in the stationary anode tube.

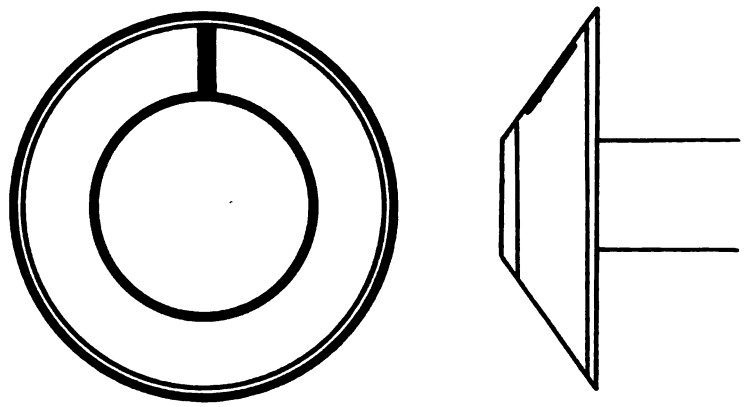


FIGURE 25. — ROTATING ANODE STRUCTURE

Obviously, from the foregoing, heat within the anode structure is of a major concern. The amount of energy contained in a stream of electrons passing from filament to anode is tremendous, but unfortunately, no way has yet been found to convert more than a very small fraction (less than one percent) of that energy to useful x-ray. It is heat, then, which limits the application and usefulness of the x-ray tube. Heat generated in an x-ray tube during bombardment of the target by electrons is calculated in terms of an arbitrary heat unit which is the product of kv × ma × seconds — 90 kv × 100 ma × 1/20 second = 450 heat units.

Focal Spot

In the design of the anode structure of the x-ray tube, the face of the anode, or the area of bombardment by the electron stream, is not perpendicular but is constructed at an angle — 20° in stationary anode tubes, 17° in the rotating anode tube. This is done to direct most of the x-rays, produced at the target, outside the tube where they may be usefully employed. In modern x-ray tubes, the electron stream from the filament is rectangular in shape, and likewise, the area of bombardment is rectangular. Hence the term, line focus. Such design results in an ACTUAL and an EFFECTIVE or projected focal spot size. The former is of interest to the design engineer and is determined partially by the size of the filament and the angle of the anode face. The latter, effective or projected focal spot size, is of interest to the technician, and is measured at a point directly beneath the target area at right angles to the long axis of the anode. The effective focal spot size is the one referred to in tube rating charts and all literature concerning the x-ray tube.

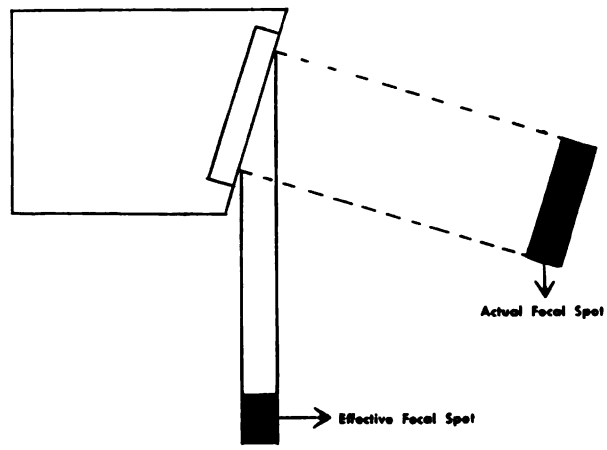


FIGURE 26. — ACTUAL AND EFFECTIVE FOCAL SPOTS

The third part of an x-ray tube is the glass envelope or bulb enclosing the cathode and anode structures. This Pyrex glass envelope serves several purposes, the principal one being to maintain the cathode and anode in a high vacuum. The vacuum is necessary to prevent burn out of the filament due to heating in air. Too, if there were any gaseous air particles in the path of electrons passing from the cathode filament to the anode, the electron stream would bombard these particles producing undesirable results. Finally, the vacuum serves as an electrical insulator between cathode and anode structures preventing an electrical discharge between these two structures.

Another purpose of the glass envelope is to serve as a support for the cathode and anode, holding these structures firmly in their proper relative positions. Glass, being an excellent electrical insulator, safely withstands the high voltage impressed across the tube. Pyrex glass is used because of its heat tolerance and because it has proper physical characteristics to make it adaptable to metal-to-glass vacuum tight seals.

X-RAY TUBE RATING CHART

Practically every possibility of electrical or mechanical failure can be taken care of in the design of equipment, but certain responsibilities, particularly those governing satisfactory x-ray tube life, remain delegated to the individual technician. The useful capacity of an x-ray tube cannot be guessed at or even intelligently estimated, but rather is determined along rigid lines by the design engineer who then supplies a rating chart to govern safe use of the tube. What is a tube rating chart? It is a pre-determined answer to the question of how much kilovoltage and how much milliamperage can be impressed on a given size focal spot for how long a time. The interpretation of a tube rating chart is one of the most important things a technician can learn; it can represent the difference between satisfactory long life or one-time use of an x-ray tube. Equally important to the use of a chart is the use of the correct chart for the particular tube, specific focal spot of the tube and the type of rectification.

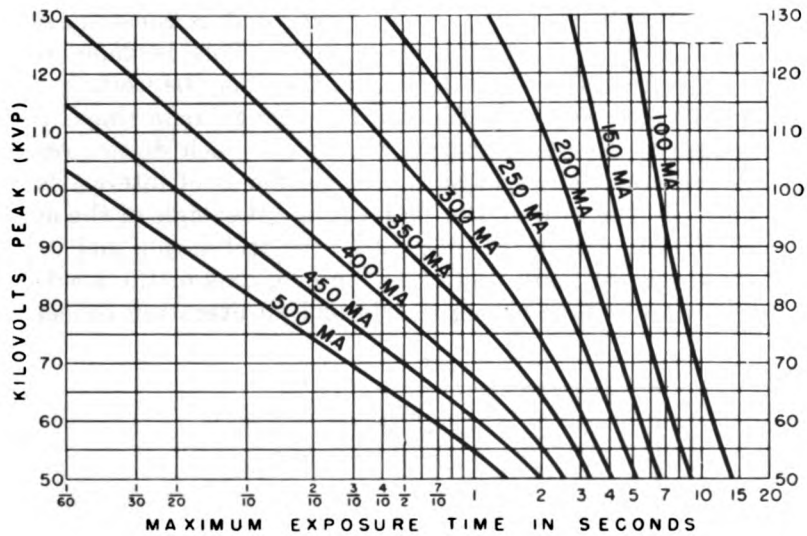


FIGURE 27. — X-RAY TUBE RATING CHART

PURPOSE AND INTERPRETATION

In this model tube rating chart, horizontal lines indicate kilovoltage values, listed on the left side of chart; milliampere values are indicated by the various curved or diagonal lines; time of exposure in seconds is indicated along the bottom of the chart coincident with the vertical lines. A typical question arises when kilovoltage and milliamperage are known, but the time of exposure, using these known factors on a specific size target, is not known. To determine a safe exposure time, locate the proper kilovoltage line, follow it to the point of intersection with the known milliampere line. From this intersection point, follow the vertical line to the time value at the bottom

of the chart. If kilovoltage and milliampere lines do not intersect at one of the specific time lines, drop an imaginary line from the intersection point and interpret the time value between two given values on the chart. Example: 85 kvp and 150 ma would be safe for a 5 second exposure, and 85 kvp at 100 ma would be safe for a 7 second exposure. It would always be safe to accept the shorter exposure time when an imaginary time line falls between two time values indicated on the chart.

ANODE COOLING CURVE

In all instances, the information taken from a tube rating chart is for one single exposure. However, there are instances when repeated exposures may generate heat so rapidly that some maximum value may be reached or exceeded and it becomes necessary to know the heat-dissipation rate of the particular anode. In such cases where a series of high energy exposures are rapidly repeated, any one of these exposures may be within the safe limits of the tube for a single exposure but it is necessary to avoid the possibility of overheating the anode due to the series. A cooling curve chart is provided with each tube to indicate the rate at which heat is dissipated in terms of minutes. This chart must be consulted prior to making a series of high energy exposures. Both the tube rating chart and cooling curve are important to the completely satisfactory operation of an x-ray tube, and should be placed in a conspicuous position alongside the x-ray technique chart.

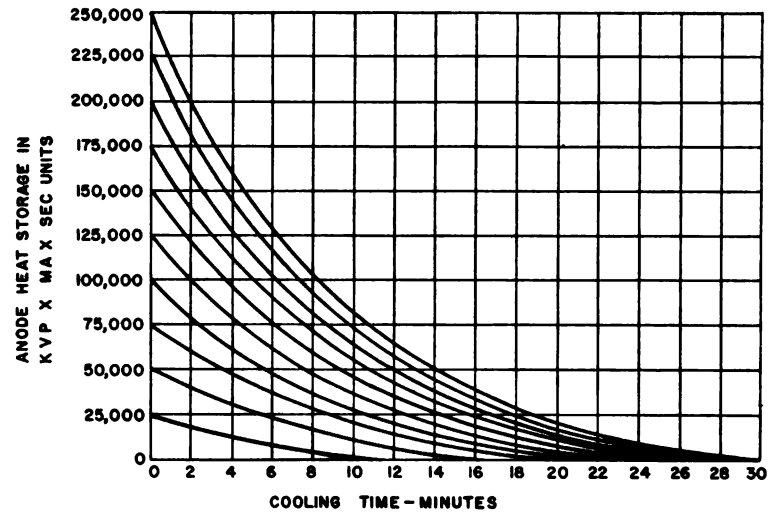


FIGURE 28. — ANODE COOLING CURVE

PURPOSE AND INTERPRETATION

The example cooling curve, shown in Figure 28, indicates an anode heat storage capacity of 250,000 heat units. It has already been indicated that anode heat units are the product of kvp × ma × seconds. To interpret a cooling curve, figure the total heat units in an exposure, and locate that value on the left side of the chart. Follow the appropriate curved line to a point of intersection with the vertical line closest to right side of chart; that vertical line indicates, in minutes, the time necessary to completely dissipate heat from the anode. Example: A series of rapidly repeated exposures has put 150,000 heat units in an anode. Locate the figure, 150,000 heat units and follow that curved line and notice that it terminates at the vertical line indicating 24 minutes. Wait 24 minutes and put the 150,000 heat units in the tube again. Notice, too, that the 150,000 curve crosses the 6 minute line at the 75,000 horizontal line. Then, the original 150,000 heat units have dissipated to 75,000 in 6 minutes; they have dissipated to 25,000 in 14 minutes. After a 14 minute wait, a total of 225,000 heat units can be put on the anode. Then the maximum of 250,000 has been reached. To permit the tube anode to reach zero heat from that maximum, a waiting period of 30 minutes is indicated on the chart.

A brief study of the chart indicates that it would be impossible to reach or exceed the maximum heat storage capacity of this particular anode by conventional, routine technical procedures. However, during fluoroscopy as well as any series of rapidly repeated exposures, it is good technique to determine the heat units per exposure and multiply that by the total number of exposures. It is better to have that answer before starting the series than to wonder about it when the series is half completed.

HEEL EFFECT

A point of particular interest in the use of x-ray tubes, and of which technicians should be very conscious in certain types of radiography is the heel effect. X-radiation is distributed from the focal spot of the tube in a hemispherical shape, and the heel effect is described as an unevenness in the intensity of x-radiation over the limits of this hemisphere. Because of the heel effect there is a difference in density in that section of a film at the cathode end of the tube in comparison to the density in the section of film exposed by the anode portion of the hemisphere of x-ray.

This heel effect is present in all exposures, but is more effective on film density at shorter target-film distance. For this reason, a technician should be very conscious of the heel effect when doing bedside radiography. Very often, because of circumstances, target-film distance for bedside radiography is less than thirty-six inches. In conventional radiography, at a forty inch or greater target-film distance, this heel effect is not so evident on a radiograph. Likewise, when only small size film are exposed, or a beam of x-ray is coned to a small field, the heel effect is not evident on a film. It is most noticeable in radiographs when the entire long dimension of a large film is used.

The rule to follow to obviate the change in density resulting from the heel effect is: Align the long axis of the x-ray tube parallel with the long axis of the object, and place the heavier or more dense portion of the object at the cathode end of the tube. Then the increase in radiation intensity in the cathode portion of the beam will be effective in producing proper film density where the object is more dense and absorbs more of the x-rays.

Example: Bedside radiography of a femur. There is considerable difference in volume and opacity of tissue at the proximal and distal ends of femur. To avoid a noticeable difference in film density resulting from this variation in the object, place the cathode end of the x-ray tube at the proximal end of the femur. Other areas of the body where a similar problem may arise in bedside radiography are: the thoracic spine (both aspects), abdomen, lateral lumbar spine.

There may be a question sometimes as to which end of an x-ray tube is the cathode end. If there is a translucent window in the tube casing and filters are not permanently fixed in place, turn on the filament and look in the tube. Many modern x-ray tubes have an indication on the outside of a tube casing to show anode and cathode ends. If neither of these methods apply, do this — Stand, facing the tube in its usual horizontal working position, and the anode is to the left-hand side.

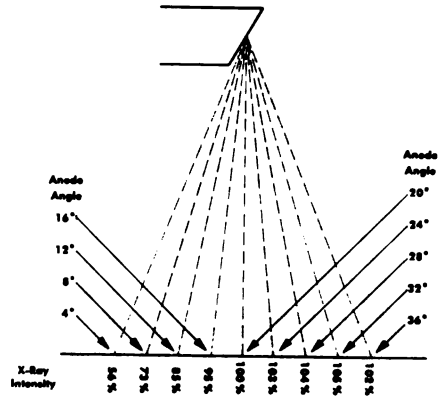


FIGURE 29. — ANODE HEEL EFFECT

PINHOLE RADIOGRAPHY OF FOCAL SPOT

At times there may be interest in measuring the effective focal spot size in an x-ray tube. For absolute accuracy, such a measurement should be done with laboratory control, but for general purposes, the following method of "pinhole" radiography will serve the purpose. Place the x-ray tube with focal spot at some specific distance from a film (20 inches); place a sheet of lead with a small pinhole exactly halfway (10 inches) between focal spot and film. Make only a minimum exposure to avoid penumbra effect around the small rectangular spot exposed on the film which indicates the focal spot. Measure the size of this spot. Focal spot size is the size of this spot less twice the diameter of the pinhole in the lead sheet.

REVIEW QUESTIONS

1. The essential component parts of an x-ray tube are:
2. Discuss briefly the cathode structure and its purpose in the x-ray tube.
3. Discuss the anode structure, its components and purpose.
4. Why is heat of such concern in an x-ray tube anode? What are heat units and how are they determined? What is the particular advantage of a rotating anode tube over a stationary anode?
5. Which of these sets of exposure factors is advantageous from the standpoint of heat units: 80 kvp × 100 ma × 1/10 second, or 80 kvp × 300 ma × 1/30 second, or 95 kvp × 100 ma × 1/20 second?
6. What is the difference between actual and effective focal spot size in an x-ray tube?
7. What is the difference between a 2 mm. focal spot in a stationary anode tube versus a 2 mm. focal spot in a rotating anode tube?
8. What is the purpose of the Pyrex glass bulb used in x-ray tubes?
9. What would happen if the filament of an x-ray tube were heated in the pressure of air?
10. If a 2 mm. stationary anode tube will safely tolerate an exposure using 75 kvp, 50 ma, 4 seconds, would it accept 70 kvp, 100 ma, 6 seconds?
11. What is a tube rating chart and how is it interpreted? Where is the tube rating chart in your department?
12. May you safely make thirty rapidly repeated exposures using 85 kvp and 15 mas per exposure when the x-ray tube anode in use has a maximum heat storage capacity of 100,000 heat units? What if the tube has just completed a series of exposures and accumulated 14,000 heat units?
13. Discuss self-rectified operation of an x-ray unit.
14. What are valve tubes? What is full-wave rectification? Discuss it.
15. Is there any particular advantage in self-rectified equipment compared to a full-wave generator?
16. What is the difference between method of operation of a valve tube and an x-ray tube?
17. If you understood the circuitry of a four-valve, full-wave x-ray generator, and could draw such a circuit, where would the difficulty likely be located when a chest radiograph on a 25 cm. patient, (using 65 kvp, 200 ma, 1/20 second), is not diagnostic?
18. How would you overcome the heel effect in bedside radiography when it is not possible to align the long axis of the x-ray tube parallel with long axis of femur?

ANSWERS

ANSWERS

Chapter 5

X-RAY FILM AND PROCESSING

HISTORY OF X-RAY FILM

The definition of x-ray concluded with the phrase, "and can record an image of that tissue on a photographic emulsion". A photographic emulsion, coated on some type of carrier, is the recording medium used in medical radiography. The first radiographs were exposed on an emulsion coated on one side of a glass plate. Glass plates continued to serve this purpose until about 1914 when the principal source of supply for such glass was cut off by World War I. In 1914, a film with the emulsion coated on one side of a base of cellulose nitrate was introduced. The demand for shorter time exposures brought about the development of a double-coated film on a cellulose nitrate base in 1916. Nitrate base film continued in use, despite the great fire hazard of such material, until about 1924 when the first safety film with a cellulose acetate base was marketed. Since that time x-ray film development has been directed primarily towards obtaining greater emulsion speed, or response to x-ray and light, so that radiation might be reduced and exposure time shortened. A film with blue-tinted base was introduced in 1933 and in 1936 the first non-screen or direct exposure film was manufactured.

X-RAY FILM CONSTRUCTION

Modern x-ray film is composed of two parts, (1) a base and (2) an emulsion. The base consists of a blue-tinted sheet of cellulose acetate coated on both sides with a sub-coating of an adhesive material to prepare it for the emulsion. The emulsion is manufactured by adding in total darkness a potassium bromide solution and a silver nitrate solution to a solution of gelatin. In combination, these solutions form silver bromide in gelatin. This creamy emulsion is heated and then cooled to a jelly-like substance. Undesirable potassium nitrate is washed out of the material prior to reheating and coating on both sides of the acetate base. Film base is about eight thousandths of an inch in thickness and each emulsion is about one-thousandth of an inch thick. The double coating of emulsion serves to increase the sensitivity of the film to x-ray and light such as that given off by intensifying screens.

TYPES OF X-RAY FILM

There are two general types of x-ray films. One carries an emulsion which will respond to direct x-ray exposure and/or to light coming from intensifying screens and is called "regular" film. The other, carries a thicker coating of emulsion, which will respond best to direct x-ray exposure and only very slightly to light from intensifying screens. While called direct exposure film this film is more commonly termed "no-screen" or "non-screen" film. Direct exposure film is considerably faster than regular film when exposed without intensifying screens, and is used specifically in radiography of small extremities and some special studies.

Inasmuch as either non-screen film or regular film without screens may be used satisfactorily in radiography of the extremities, it is of interest to know the comparative speed of the two films as well as other comparable features. The non-screen type film has an inherent higher speed because of a thicker emulsion with more and larger silver bromide crystals; under comparable conditions, it is capable of producing shorter scale contrast than regular film; non-screen film does not clear or fix as rapidly as regular film during the processing cycle; when full advantage of

film speed is taken by reduced exposure, then non-screen film requires two minutes longer developing time than regular film at a given temperature. However, this differential in developing time between the two types of films may be discounted if some speed in exposure is sacrificed. For example, instead of giving the direct exposure film only one-eighth as much exposure as regular film in cardboard holder, give the direct exposure film one-sixth as much exposure. Then both films may be developed at the same time and temperature. The non-screen film cannot be developed in an automatic film processor because the cycling of that unit is based on a time-temperature-chemical combination satisfactory for screen-type film. Figure 45 indicates the comparative speed of various types of film when normal exposure and processing methods designed for each film are used.

A special type of x-ray film, with emulsion on only one side of the base is used in certain special applications such as photo-fluorography where the film records an image formed on a fluoroscopic screen. This film, is also used with a single intensifying screen for special types of radiography where long-scale contrast may be advantageous.

It has been previously stated that the emulsion of an x-ray film consists of silver bromide crystals uniformly spread throughout the emulsion. When the emulsion is struck by x-ray and/or light, a chemical change in the silver bromide takes place. The change is proportional to the amount of exposure received by the silver bromide crystals. If an object of varying size or opacity is interposed between the source of x-ray and the film, that object will absorb incident radiation in accordance with its opacity and hence different amounts of radiation will be transmitted to the film. The chemical reaction in the silver bromide crystals will vary in proportion to the amount of this transmitted radiation reaching the film. Thus a latent image of an object is formed in the film emulsion, and developing makes this image visible.

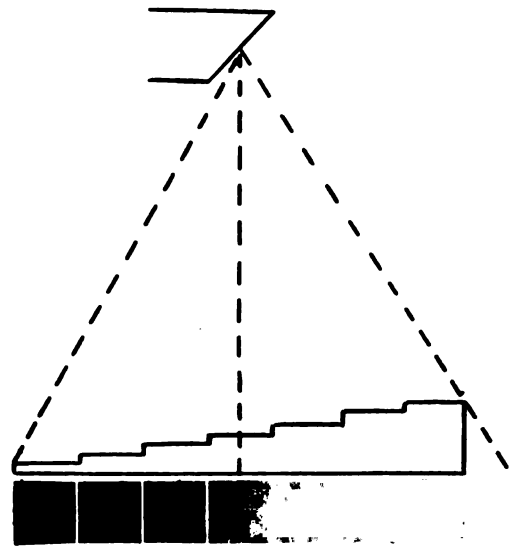


FIGURE 30. — OBJECT STRUCK BY X-RAY

THE LATENT IMAGE

Microscopically, it would be seen that an x-ray film emulsion is made of a multitude of small, vari-shaped, closely-packed crystals of silver bromide in gelatin. When the silver bromide crystals are struck by x-ray or light a chemical change takes place, resulting in formation of what is known as a latent image.

The formation of the latent image is a complicated chemical procedure. The addition of certain chemicals in the process of emulsion making causes formation of tiny specks of silver sulphide on the surfaces of the silver bromide crystals. Not all silver bromide crystals acquire these specks, and unless such a speck is part of a silver bromide crystal, that crystal will not be subject to development. These tiny silver sulphide specks are actually centers of development. Under the in-

fluence of exposure and subsequent ionization action within the silver bromide crystals, the speck will continue to grow or expand and attract more and more silver from within the silver bromide crystal. The amount of silver attracted to this little speck is proportional to the amount of exposure — heavy exposure produces much silver, lesser exposure causes a smaller deposit of silver at the development center. A patient of varying size and/or opacity, interposed between a source of x-ray and the film, will absorb and allow transmission of x-radiation in accordance with part opacity. This variable amount of x-radiation striking the film emulsion accounts for the variable amounts of silver attracted to the development centers of each of the multitude of silver bromide crystals. Thus, a latent image of the object is formed in the film emulsion, to be reduced to a visible metallic silver image upon development.

In the developer, reducing agents remove bromide only from the specks which have grown sufficiently and attracted enough silver to become developable. The change from silver bromide crystal to metallic silver does not take place unless a speck received enough exposure.

X-RAY FILM PROCESSING

Processing an exposed x-ray film is a photographic procedure with one purpose — to make the latent image visible. Production of a diagnostic radiograph requires two equally important steps, correct exposure and proper processing. The effect of the former can be mitigated or ruined by improper processing. However, proper processing will not recover an incorrectly exposed film. It is not logical to spend month's learning how to expose radiographs, to acquire a proficiency in calculating exposure and manipulating technique, and then either neglect to learn proper processing procedures or carelessly acquire bad habits in film processing.

Processing a film follows a series of organized procedures, each meshing into a successive step to complete the whole process. A mistake in any step cannot be rectified in the successive one. Proper processing includes:

1. Preparation of the film for development
2. Development
3. Rinsing
4. Fixing
5. Washing
6. Drying

Each of these procedures is discussed below:

Preparing the film for development involves removal of the film from its container without creasing or bending the film. The film should always be handled only by its edges and with dry hands. It must be securely attached to the film hanger. All this must be done without unnecessary or prolonged exposure of the film to a darkroom safelight.

Developing

An x-ray developer is basically an alkaline solution, formulated from several chemicals, each designed to make a specific contribution to proper development. An x-ray developer has just one job to accomplish and that is to reduce exposed silver bromide crystals to black metallic silver while not affecting those crystals that have not been exposed. If a portion of the film has been exposed to direct radiation the developer will reduce most of the silver bromide to black metallic silver. Where the direct radiation has been filtered by passage through the patient the silver bromide will be reduced only partially by the developer and those areas of the film will be shown as shades of gray rather than black. If a part of the film has not received any x-ray exposure, no reaction has taken place in the original silver bromide crystals and hence the developer should have no effect on these crystals.

There are generally five chemical ingredients in a developer solution. Two of these, METOL and/or PHENIDONE and HYDROQUINONE, are known as reducing agents or developers since they have the chemical ability to reduce exposed silver bromide to metallic silver. Neither of the two, used alone, would accomplish the task but in a balanced compound, they work to produce the shades of gray and jet blacks essential in a radiograph. Each of these chemicals has its own properties or characteristics which compliment each other. Metol is not critically affected by the temperature of the solution. It begins to work on the exposed emulsion very quickly and, in general, produces the gray tones of the film. Hydroquinone is sensitve to temperature, becoming inactive in cold developer. It works slowly and is responsible for the blacks of the film. Hydroquinone works most efficiently when solution temperature is in the 65° - 70° F. range. This accounts for the usually recommended developer temperature of 68° F.

A chemical ingredient must be used to open the pores of the film emulsion and allow the developing agents to do their work. This chemical is an ALKALI and must be present in the solution in a balanced amount since too much alkali opens the emulsion pores too quickly and tends to cause a chemical fogging of the film before development is complete. Too little alkali in the solution retards development to the point that a film acquires a chemical fog before development is complete. Liquid concentrate developers often contain one of the caustic alkalis, sodium or potassium hydroxide, whereas the so-called regular or powdered developers may use the carbonated alkalis, sodium or potassium carbonate.

Two actions tend to exhaust a developer solution: (1) the reduction of silver bromide to metallic silver on films processed; (2) oxidation of the solution by air. To slow down oxidation by air the fourth chemical ingredient, a preservative, usually SODIUM SULPHITE, is added in order to extend the useful life of the developer.

To inhibit the tendency of the developer to develop unexposed portions of a film a restraining agent, in the form of a BROMIDE, is added to the solution. While this retards the build up of chemical fog, the bromide also tends to retard the development process, so restrainer is added to the original solution in a critical proportion to create the desired balance between the above effects. In addition to the bromide intentionally added, some bromide is removed from each film during development, and eventually, an over-abundance of bromide accumulates in the solution. This, in combination with the gradual exhaustion of the developing agents, dictates that development time must be increased after a number of film has been developed, or a method of replenishing the strength of the exhausted chemicals must be used if it is desired to maintain the development time constant for a given temperature.

Development Replenisher

How long may a tank of developer be used? As long as it continues to produce the same film density for a given x-ray exposure. To do this the strength of the developer must be maintained at its original level even after hundreds of films have been developed. Not only must the volume of the solution in the tank be replenished to a level necessary to cover the films, but an adequate amount of a replenisher-developer must be used to offset the waning strength of the original developing agents. Replenisher-developer will contain more of the developing chemicals and more of and/or stronger alkali than the original developer, with very little or no bromide, since this is being added from films passing through the developer.

Developing Time

There is only one correct method to develop an x-ray film — the time-temperature method. This statement holds true, perhaps, even more true, with films exposed with unproven technical factors. Since the patient is a variable and exposure factors are variable dependent upon the circumstances, it is imperative that a standardized non-variable developing procedure be followed or it will be impossible to produce films of diagnostic quality. The only practical step to standardize in the whole film production process is film development.

It has been pointed out that developing an x-ray film is a photographic procedure. It is a good photographic principle to develop a film as long as possible without producing chemical fog. Accordingly, it is recommended that films be developed for 5 minutes at 68° F. temperature, with no inspection of developing progress after 1, 2, 3, and 4 minutes. If temperature of the developer increases above the recommended 68°, subtract one-quarter minute developing time per degree of increased temperature; when temperature decreases, add one-quarter minute developing time per degree of decreased temperature.

Occasionally in order to speed up the development procedure films may be developed on the basis of three minutes at 68° F. temperature. In these days of concern with reduction of radiation to the patient, it does not seem logical to follow a short-time developing procedure at 68°. To do so requires that films be given approximately twenty-five percent more exposure to produce comparable film density as compared to the exposure required for the film developed five minutes at 68°. If speed in the darkroom is so essential that films must be developed in three minutes, then raise the developer temperature to 76° and use the same exposure factors as though a 68° temperature were used for five minutes. In lieu of this, use one of the recently introduced high-energy developers which will permit short-time development together with reduction of exposure to the patient.

Agitation of Films

It is good processing technique to agitate films periodically during development. Initial agitation of the film after immersion in a developer is done to dislodge any air bubbles clinging to the emulsion. Development would be retarded in an area where an air bubble happened to attach to the film emulsion. Several times during the developing cycle, the films should be agitated in order to replace the portion of developer in immediate contact with the film emulsion. Contrary to some opinions, agitation does not increase film density, but it does provide for a more even or uniform development of the film. Adequate agitation is provided when films are raised vertically in the solution and "swished" or waved from side to side in the tank for a few seconds. Agitation to provide uniform development is proper for all films, but especially so, when the object radiographed varies considerably in opacity in adjacent areas. Heavily exposed silver bromide in areas of little object opacity and lightly exposed emulsion in areas of extreme object opacity might cause a "running down" of the emulsion over adjacent film if agitation is not practiced.

Rinsing the Film

A film, being removed from the developer, is saturated with alkaline solution that should be neutralized or greatly diluted before the film is immersed in the fixer. A water rinse is commonly used for this purpose. No reasonable rinsing time in water will completely neutralize the alkalinity carried over from the developer, but a thorough rinsing with agitation for not less than thirty seconds, will sufficiently dilute the alkali and prevent excessive carry-over to the fixer. Thorough rinsing with agitation presupposes total immersion of the film and hanger in water.

A more efficient rinse is an acid stop-bath, either two and half quarts of 22% Acetic Acid or twenty-two ounces of Glacial Acetic Acid with water to make five gallons of solution. An acid stop-bath stops development immediately and it also neutralizes the developer alkalinity of the film before it is placed in the fixer. The film should remain in the acid stop-bath at least thirty seconds, again with agitation, and need not be rinsed in water, although it should be well-drained of excess solution before immersion in the fixing solution. Use of an acid stop-bath rather than a water rinse after development, and passing the film directly from the stop-bath to the fixer tends to prolong the life of the fixer by retarding dilution of the acid in that solution.

Fixer

Exposure and development reduces to metallic silver only a relatively small portion of the silver bromide in a film emulsion. In order to make a permanent image, the unexposed, undevel-

oped silver bromide must be removed from the film. To accomplish this purpose, as well as prepare the film for permanency, is the function of the fixing solution. The fixer is formulated from several chemicals.

A clearing agent in the solution removes the undeveloped silver bromide. This agent is either SODIUM THIOSULPHATE (HYPO), as used in regular fixer; or AMMONIUM THIOSULPHATE, used in liquid high-speed fixing solutions.

An acidifier, ACETIC or SULPHURIC ACID, in dilute concentration, serves to neutralize any alkali remaining on the film after developing and rinsing. Complete neutralization of the alkaline developer must take place before fixing can begin. If an acid stop-bath is used between developer and fixer, neutralization is largely accomplished in the stop-bath. A water rinse requires that the acidifier in the fixer perform this neutralizing action.

A preservative, SODIUM SULPHITE, is used to retard oxidation of the alkaline carryover from the developer which may stain the film. This is particularly true when only a water rinse is used between the developer and the fixer.

A hardener, such as ALUM, used in a regular fixing solution, or ALUMINUM CHLORIDE, used in a high-speed fixing solution, shrinks the emulsion to prevent swelling or softening and absorption of water in the final wash. In addition, the file life of a radiograph is of indefinite duration, usually several years at least, and during this time the film may be handled often. The hardener in a fixing solution toughens the film emulsion to withstand this handling.

Because there is some carryover of water or stop-bath to the fixer, plus the fact that films should be well drained before removal from the fixer, there is less carry-out of the solution than is the case with the developer. Ordinarily, the level of solution does not decline as is the case when dry films are placed in the developer and absorb some solution. Replenishment of the fixer, then, would be done not because of a normal decline in solution level, but rather in order to maintain a desirable short fixing time during the life of the solution. To replenish fixer, this procedure may be followed: When the equivalent of one hundred 14 × 17 films have been fixed in ten gallons of fixer, dip out seventy-two ounces of solution from the tank and replace with two quarts of UNDILUTED fixer concentrate and eight ounces of UNDILUTED hardener. This process may be repeated twice for the life of a tank of fixer solution, and by such means, the fixing time may be kept to a minimum as with a tank of fresh solution. Note, though, that UNDILUTED solution is added as replenisher after some partially exhausted fixer has been removed from the tank. The accumulation of silver in the fixer eventually causes the solution to deteriorate to a non-useful point even though chemical replenishment is adequate.

In use there are two indications which serve to determine the useful life of the fixer — clearing time and fixing time. Clearing time is the length of time needed to completely remove the undeveloped silver bromide from the film. This time is variable, dependent on the activity of the clearing agent (sodium or ammonium thiosulphate) in the solution; freshly mixed fixer will clear a 14 × 17 film in less than one minute, but after a volume of film has passed through the solution, it may require two to three minutes to completely clear a film. A rule of thumb indicating that the fixer is exhausted is a factor of three. When the original clearing time has increased by three times the fixer should be considered exhausted, i.e., original clearing time of one minute has increased to three minutes. FIXING TIME IS TWICE THE CLEARING TIME. The film that clears in one minute is permanently fixed in two minutes and nothing is gained by leaving this film in the fixer for a longer time. In fact, tests have indicated that prolonged fixing is more harmful to the keeping qualities of a film than slight underfixing.

Delay in making radiographs available to the radiologist from the darkroom is not so much the result of full and proper five-minute development as it is allowing the film to remain overly long in the fixer.

Working temperature of the fixing solution should be the same as, or within a few degrees, of the developer. In fact, the temperature of all the processing solutions and the rinse water should be as close to the same temperature as possible to prevent the possibility of a crinkling (reticulation) of the emulsion.

Final washing of the film is designed to remove most of the chemicals remaining in the emulsion after processing. All of these residual chemicals cannot be removed because the fixer hardener shrinks the emulsion and locks in small quantities of the various chemicals. Proper washing will remove enough of the residual chemicals to forestall for a reasonably long time fading and deterioration of the image. Washing time is determined by the speed with which the clearing agent (sodium or ammonium thiosulphate) is washed out of the emulsion. If the film is washed in freely-running fresh water, the amount of residual clearing agent is continually halved in the same period of time as washing continues. In other words, if half the clearing agent is removed in three minutes, half of the remainder is removed in six minutes, half of the remainder in nine minutes, and so on until the amount of residual chemicals is reduced to an acceptable level. Practically speaking, if the flow of water is such that the wash tank fills and empties three to four times an hour, films can be considered sufficiently washed in thirty minutes.

The above assumes that the film has not been over-fixed and that the water temperature in the washing tank is 68° - 72° F. Excessively cold water — below 50° F. — should not be used for the washing process, since water at such a low temperature will not remove the residual chemicals in any reasonable length of time.

Another solution is sometimes used between the fixing and washing cycles of the processing procedure. This is called FIXER-NEUTRALIZER. This solution has no beneficial effect when films have been over-fixed, but with films that have been properly fixed, immersion in a fixer-neutralizer reduces film washing time from the usual thirty minutes to only five minutes. If adequate drying facilities are available, the rapid washing of films after the use of fixer-neutralizer may effectively increase the volume of films that can be processed.

In many darkrooms, films taken from the final wash are placed in a tank containing a WETTING AGENT for two to three minutes. The purpose of a wetting agent is to reduce the surface tension of water so that it will drain more rapidly from the film and help to prevent the formation of water spots during the drying period.

The film must be dried before it is ready for interpretation, and even though a film has been properly exposed and correctly processed up to this point, all previous work can be negated through improper drying. Interspacing large size films with smaller sizes and assuring that all corners of the films are firmly pinned in the film hanger is insurance that films will not buckle and adhere to each other during the drying stage. To prevent brittleness films should not be subjected to excessive heat while drying.

When a film is removed from the dryer in satisfactory condition, processing procedures are complete. Rough corners on the film are removed, all films in a series are gathered together and prepared according to the routine of the department for presentation to the radiologist for interpretation. Each department works out a routine in this regard, so no effort is made here to offer any suggestions that might be interpreted as conventional in all departments. Bear in mind that a patient's examination is not complete until every film has been submitted for interpretation, interpreted and committed to its proper place in the file.

Automatic Film Processing

In recent years, automation of film processing has become a fact. Several types of automatic film processors are in use, even in departments where relatively few films are processed during a day. Regardless of total film volume passing through a darkroom, automatic film processors have gone far towards eliminating errors and acquired bad habits in film processing. However, even these automated machines may malfunction if the technician fails to follow directions. Prior to operating an automatic processing unit it is important to study the operating directions. Some of these units use special formulations of chemicals in the developing and fixing portion of the processing cycle at higher-than-conventional temperatures so that the entire cycle from the time a film enters the machine until it emerges as a finished radiograph consumes as little as seven minutes.

A number of advantages are immediately obvious when an automatic film processor is used, such as the elimination of any need for a provisional interpretation of wet films, uniform processing, available facility for considerable expansion of work load, and others. Possibly one of the best advantages of such a unit is the fact that it almost forces a technician to develop and practice good technical methods because there is no chance to even try correcting a faulty exposure by departure from established processing methods. In the overall combination of efforts and methods to improve patient care by efficiency, an automatic film processor is the latest addition.

Darkroom Illumination

A subject closely associated with film processing is safelight illumination in the darkroom. Any photographic emulsion, including x-ray film, can be exposed by white light or x-radiation, and for this reason a film must not be subjected to white light for any time nor to filtered white light for an indefinite period of time. A darkroom safelight is safe for only a certain length of time, after which a film exposed to such light takes on a supplementary density in the form of fog.

Light from an electric light bulb is made up of all colors of the visible light spectrum and will form a continuous band of colors if passed through a prism although some colors will be more evident than others. Because the colors of light given off by the light bulb are of different wave lengths it is possible to filter them or to absorb some wave lengths while passing others. An x-ray film is most sensitive to violet and blue light although it is sensitive to other colors to a lesser degree. The darkroom safelight is generally equipped with Wratten series 6B type filter, or an amber colored acrylic plastic filter. The light emitted is in the yellow and yellow-red portion of the spectrum which contributes the least to fog formation.

There is no "regular" or "standard" amount of filtered light, or any specific wattage of light bulb, that can be used in darkroom safelights without testing for safety under the same conditions films will be handled in the darkroom. To make such a test, follow this procedure:

1. Use pre-exposed screen type film. (A conventional chest radiograph serves the purpose).
2. Remove film from cassette in total darkness. Place on loading bench. Cover all but one section of the film with opaque paper or cardboard. Turn on all safelights to be used in conventional operation of darkroom.
3. Expose uncovered section of film to one minute safelight. Expose successive sections to two, three, four, five, six minutes safelight. One section of the film must receive no safelight exposure.
4. Turn off all safelights. Develop film by time-temperature method with no inspection of film during development. Complete processing of the film and dry.
5. Inspect sections of the film for added density in comparison to section which received no

safelight exposure. The section which shows a noticeable increase in density indicates the maximum time for safely exposing films to darkroom safelight.

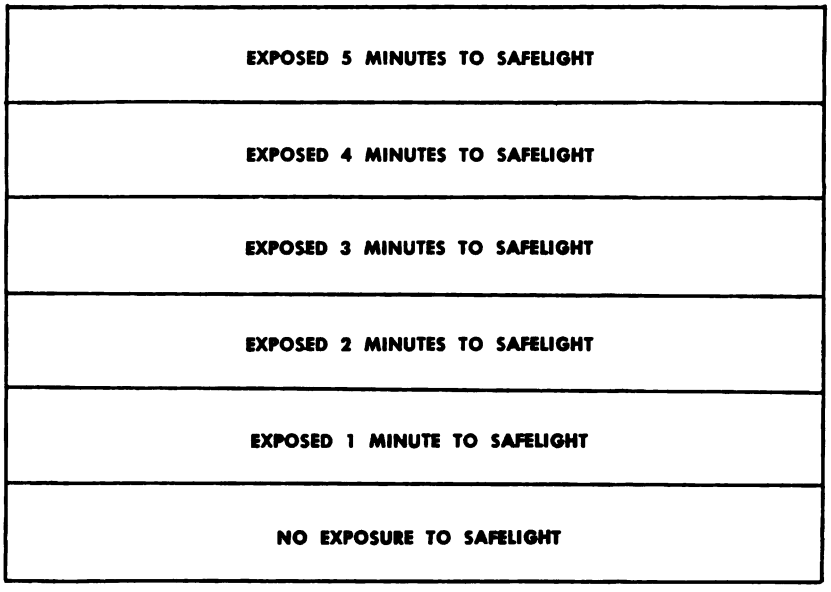

EXPOSED 5 MINUTES TO SAFELIGHT
EXPOSED 4 MINUTES TO SAFELIGHT
EXPOSED 3 MINUTES TO SAFELIGHT
EXPOSED 2 MINUTES TO SAFELIGHT
EXPOSED 1 MINUTE TO SAFELIGHT
NO EXPOSURE TO SAFELIGHT

FIGURE 31. — SAFELIGHT FOG TEST FILM

This test should be made with a pre-exposed film since it is approximately eight times more sensitive to fog than unexposed film; also the test results should be accepted as reliable, only in a specific darkroom under a specific set of conditions.

Safelight fogging of films is inexcusable. The danger of such fogging becomes more acute as film manufacturers continue to increase the speed of x-ray film. Whenever an unfamiliar brand or different type of film is handled in a darkroom, test the safelights.

DO'S AND DON'T'S IN THE DARKROOM

The logical time to acquire good darkroom habits is in your student days. Someone has said that ninety-five percent of the films which come to an ignominious end in a waste basket instead of the permanent file reach that end because of faulty darkroom procedures. The only way to reduce this high percentage is to develop good routine in the darkroom and then not to deviate from that routine.

DO measure the liquid capacity of solution tanks. Width × length × total depth less one inch divided by 231 (cubic inches per gallon) will indicate true capacity of a tank. This is to assure the use of a correct amount of concentrate solution when mixing chemicals.

DO mix solutions carefully and completely according to the manufacturer's directions.

DO stir solutions thoroughly at least once a day or after they have stood idle for a period of time.

DO use a thermometer and DO be sure it is accurate.

DO keep the solution tanks, particularly the developer, covered when not in use.

DO maintain scrupulous cleanliness around the tanks and wipe up any accidental spillage of chemicals before some permanent damage results from the accident.

DO clean the processing tanks periodically. Even stainless steel will stain if not cared for properly.

DO maintain order in the darkroom. It was not built for use as a storehouse for miscellaneous paraphenalia.

DO agitate films periodically during development and for the first few seconds after placement in the fixing solution. This will help to prevent streaking of the film.

DO remove films carefully from the various chemicals to avoid splashing into the other tanks.

DON'T compound an error in exposure by sight-developing the film. Concede the error and correct the exposure. Sight-development does not work.

DON'T permit dripping of solution back into the developer when removing films. That is false economy because the whole tank is contaminated by the drip-back.

DON'T handle films or cassettes and DON'T go near the work bench with wet hands.

DON'T place on hangers more films than can be accommodated in the developer tank at one time, unless the extra films are completely protected against safelight fogging until put in the developer.

DON'T crowd films in the solution tanks. Leave about an inch space between hangers in the tank.

DON'T forget to cover all unexposed films before turning on any white light.

DON'T allow cassettes to stand open on the work bench.

DON'T store films with the boxes lying on a flat side. Stand them on end.

DON'T overfix films.

DON'T fail to have an adequate supply of developer replenisher mixed and ready for use at all times.

DON'T expect the darkroom technician to watch your films and attempt to correct your mistakes. She doesn't know how, and she's busy.

REVIEW QUESTIONS

1. What are the chemicals and function of each in a developer solution?
2. What is the time variation to accommodate a temperature variation from the usually recommended time-temperature combination in x-ray film processing?
3. How often should developer solution be changed?
4. What is the difference in the chemical composition of developer and replenisher-developer?
5. If a film is accidentally overexposed 100%, could it be salvaged satisfactorily by altering an acceptable developing procedure?
6. What are the chemicals and function of each in a fixing bath?
7. Distinguish clearing time and proper fixing time.
8. Films fixed in an exhausted fixing bath are difficult to dry. Why?
9. Is there a minimum time for rinsing films between developer and fixing bath? How long? Can you rinse the film properly without getting your hand wet?
10. Is there a proper temperature of water for final washing of films? How long should they be washed?
11. What happens to films left in a fresh fixing bath overnight?
12. How do you determine actual capacity of solution insert tanks?

13. How do you test safelights for fog?
14. Is the usual processing procedure for non-screen films the same as for regular films exposed in a cardboard film holder?
15. Did your instructor explain the principles of sight-developing of films? What do you think of the idea? Why do you do it?
16. What are the advantages of agitating a film in developer and fixing bath?

ANSWERS

ANSWERS

Chapter 6

RADIOGRAPHIC ACCESSORIES

In no sense are radiographic accessories to be confused with gadgets. Both, accessories and gadgets, serve a useful purpose in radiography, but whereas the conventional accessories are necessary auxiliary devices to the satisfactory accomplishment of radiography, gadgets serve more as someone's personal instrument or accessory to possibly facilitate the accomplishment of a difficult positioning problem in radiography. Too often, technicians become slaves to a gadget, and are so dependent on it that they may lose sight of the fact that there is a conventional method of solving the problem.

During the development of radiography to its present status, radiographic accessory devices have been brought forth from time to time. These not only aid in solving problems; they are necessary parts of the technician's armamentarium in the practice of radiography. It is advisable to list and discuss a number of the more common accessories used in radiography today.

TISSUE THICKNESS CALIPER

The fact that every radiographic installation now includes, or did include, a caliper for measuring thickness of tissue indicates that this device is considered to be an essential instrument in the practice of radiography. The fact that many technicians do not make use of a caliper should not be interpreted to mean that the instrument is obsolete or not essential to good radiographic practice. This, rather may be taken as an indication that the technician is quite willing and satisfied to take a chance of producing something less than the best radiograph. Non-use of a measuring caliper indicates the technician's willingness to misjudge one of the variables in radiography—tissue thickness of a body part—and to proceed with the mistaken belief that an error in this very fundamental step of good practice can be corrected later in the procedure of producing the diagnostic radiograph. The old fallacy that, "my technique has latitude" really indicates that exposure factors are so loose that an error in judgment of an inch or more tissue volume will have no bearing on the quality of the end result. Permissible error can be extended only so far before quality suffers. Use of a phototimer is the only technique method which will permit production of a diagnostic radiograph without benefit of measurement of tissue volume, but even this automatic timer will only operate satisfactorily when penetration of an average volume of tissue is adequate. Tissue volume is one of the variables that must be taken into account in the practice of any method of technique. Some methods of selecting exposure factors are more critical than others in this respect. How critical thickness of tissue can be is, perhaps, made more realistic when one realizes that the distance between these lines | | is one centimeter. There is a method of technique, practiced by many technicians, which calls for a variation of exposure factors for each centimeter of tissue volume.

Not only is it important to use a measuring caliper in determining tissue volume, but it is equally important that the caliper provide a correct measurement and that it be used accurately. The sliding member of a caliper must be parallel to the base of the instrument, and the vertical member must be perpendicular to the base. There should be only enough play between the sliding member and vertical member to permit easy movement of the sliding member.

Measurement of tissue volume is made along the imaginary line taken by the central ray traversing the body part. In some instances, there may be a pronounced variation in tissue thickness

between the extremes of an area to be radiographed and in such instances, it may be good technical practice to measure the greater and lesser volumes and determine an average thickness between the two extremes.

The advent of automatic film processing equipment and the continual efforts by film and intensifying screen manufacturers to produce faster materials, plus the definite tendency to shorter-time exposure, make the selection of exposure factors more critical and the accurate determination of variables, such as tissue thickness, more essential.

CASSETTE

This is a light-tight container, made of metal, plastic or rubber, which contains a pair of intensifying screens and in which a film is placed for screen exposures in radiography.

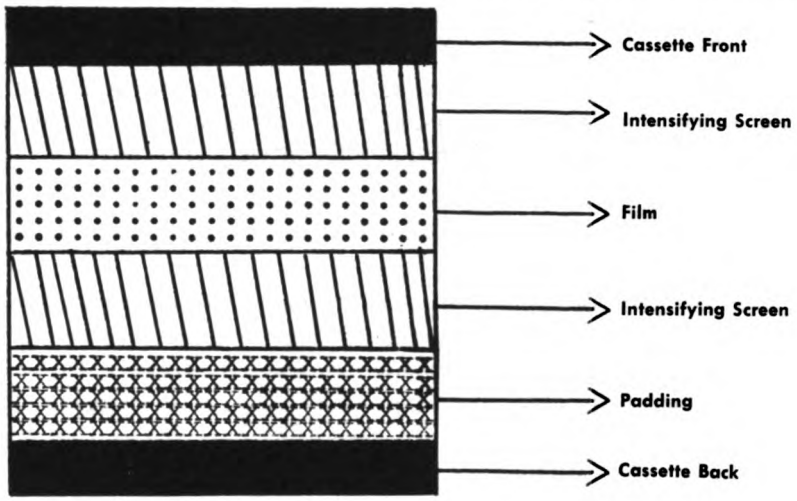


FIGURE 32. — CASSETTE WITH SCREENS AND FILM

Cassettes are one of the accessory devices a technician rapidly becomes familiar with, and sometimes this familiarity seems to breed a measure of contempt for the device. The prime purpose of a cassette is to provide a rigid support for intensifying screens so the x-ray film may be sandwiched between the screens for exposure. Obviously, the cassette must be light proof. These two requisites are not difficult to achieve in design and manufacture, but to these is added a requirement that the device be light weight. Lightness in weight is almost contradictory to rigidity, especially in view of the way cassettes are handled. Almost unlimited rigidity and complete exclusion of light could be built into cassette design, if the weight requirement were not present. Since weight is a factor the best cassette is still a compromise.

Cassette fronts are made of various materials. A plastic material offers practically no filtration effect to the passage of x-radiation but sometimes tends to absorb moisture. Consequent expansion and contraction of the plastic as a result of atmospheric conditions, ultimately may cause the material to warp. Other materials, used for cassette fronts, are aluminum, magnesium or a metal alloy. Such materials circumvent the moisture problem, but add some weight, and what is more important, they add to the filtration effect of the cassette front. Important considerations in a choice of materials to be used for a cassette front are, that the material be free from defects which could cause a pattern on a film, exposed in the cassette, that the material offer minimum filtering effect to the passage of x-radiation and that the material is rigid.

Cassette backs are usually made of metal, either aluminum or steel. There may be a thin sheet of lead foil cemented on the inner surface of the back of the cassette. The purpose of the lead foil is to assist in preventing back-scatter radiation from penetrating the cassette back to fog a film in the cassette. It is usually recommended that lead foil not be in cassettes which are to be used for phototimed exposures since even a thin layer of lead interferes somewhat with the pas-

sage of x-radiation to the fluorescent screen from which the phototube will receive light. Unnecessarily long-time exposures may result unless the phototube voltage is increased to make the tube more sensitive, and thus compensate for the lead.

One of the main purposes of a cassette is to provide a rigid support for a pair of intensifying screens so that there will be immediate contact between these screens and a film. Poor contact between screens and film, of course, results in a loss of sharpness of detail or definition in the image of an object shown on a film. Poor contact is more often the result of loss of rigidity or "trueness" in the cassette than it is a screen fault. Cassettes, particularly the larger sizes, should be periodically checked for film-screen contact. To make such a test, place a piece of 1/16 inch mesh wire on the cassette, and expose a film to 60 kvp, 2½ mas, 60 inch T.F.D. and process the film in a conventional manner. When the film is dry, inspect the image of the wire mesh for evidence of unsharpness or fuzziness. Any areas of fuzziness, where the wire mesh is not distinctly and sharply outlined, indicate areas of poor contact between screen and film. Whether or not such a fault can be corrected depends to a large extent on the condition of the cassette. If it has been manhandled, dropped, thrown around, it should come as no surprise that it is no longer "true", and this being the case, any correction of poor screen-film contact is usually only temporary. Depending on the extent of cassette damage, more harm than good is often done to intensifying screens by attempts to reestablish good contact in damaged cassettes.

FILM HOLDER

There is a choice of methods in radiography of the small extremities where radiographs may be satisfactorily exposed with the film sandwiched between a pair of intensifying screens, or exposed in a light-tight cardboard or plastic envelope to direct radiation. These other film carriers incorporate a thin sheet of lead foil in the back, again to minimize the fogging effect of back-scatter radiation. It is important that the "tube side" of these film carriers — this side is so marked — be exposed to the source of x-radiation.

A development of recent years in the manufacture of x-ray film is the enclosure of the film, for direct exposure, in a light-tight paper wrapping at the time of manufacture. It is not necessary to place such a film in any carrier before exposure. It is exposed just as it is removed from the film package, and the wrapping paper removed at the time of development.

INTENSIFYING SCREEN

Perhaps the most commonly used accessory in radiography today is the fluorescent intensifying screen. Professor Roentgen's original work, which led to his discovery of x-ray, was conducted in the presence of a barium platinocyanide screen. It was the fluorescence of this screen, when all known light from his experimental tube had been discounted, which led Roentgen to the conclusion that there must be a new radiation present. Roentgen used the fluoresence from a barium platinocyanide screen, excited by x-radiation to expose the first radiographs he made.

Shortly after this, in the course of his search for more efficient fluorescent chemicals to build a new incandescent light bulb, Thomas Edison tested calcium tungstate and found it to be considerably more fluorescent than barium platinocyanide. Edison is generally credited with the discovery of calcium tungstate intensifying screens in 1896. Undoubtedly, the first intensifying screens were crude by today's standards and they contributed little to any improvement in sharpness of detail. Nevertheless, the great reduction in exposure time, accomplished by the use of these screens, made them an acceptable accessory in radiography. In 1916, Patterson developed calcium tungstate screens for use with double-coated x-ray films, a newly developed product at that time. Since that time developmental improvements in intensifying screens have been aimed primarily towards the production of screens to provide better visualization of structural detail in radiographic images together with faster speed.

An intensifying screen is described as a sheet of radiolucent material — either specially processed cardboard or plastic — coated on one side with an emulsion of a finely powdered phospor

suspended in a suitable carrier. Phospors used today by screen manufacturers are either calcium tungstate or barium lead sulphate. The base, either cardboard or plastic, is evenly coated with a white reflecting surface on which the layer of phosphor material is coated. A thin protective material coating is put over the entire screen surface and the edges of the screen are sealed against moisture.

When struck by x-radiation, intensifying screens fluoresce with a blue-violet light to which x-ray film emlusion is most sensitive. The effect of screens is to intensify the action of x-radiation on the x-ray film emulsion. Such an effect is highly important in radiography of heavier or more opaque body parts, especially when it is recalled that less than five percent of film density is due to the effect of direct radiation, the remainder being the effect of the blue-violet light coming from the screens. Intensifying screens are mounted in pairs in the cassette by means of special adhesive tape. Some manufacturers of screens make a "thick-thin" combination in a pair of screens, and in this case, the thin screen is placed in the front of a cassette. Unless a pair of screens are marked for a specific mounting procedure by the manufacturer, either screen may be used in the front section of the cassette.

Screen fluorescence must not be confused with phosphorescence. Fluoresence ceases when the source of excitation (x-radiation) striking the fluorescent crystal is turned off; phosphoresence means that the crystal continues to emit light after the source of exciting x-radiation has been turned off. Obviously, phosphoresence cannot be tolerated in an intensifying screen because the image of an object made in a previous exposure could be transferred to a subsequent film placed in the same cassette. Modern intensifying screens exhibit no lag or phosphoresence.

Screen Speed

There are many things of interest and concern to technicians when using intensifying screens. Probably of maximum interest is the speed of screens and their ability to produce sharpness of detail. Concerning speed, intensifying screens may be generally classified in this respect as SLOW, MEDIUM, or FAST. When comparing one type with another, the speed of intensifying screens is a function of crystal size in the emulsion and thickness of the emulsion. The slowest screens have the smallest crystals and thinnest emulsion coating and consequently show the least response to the effect of x-radiation; the fastest screen have the largest crystals and the thickest coating of emulsion; hence the most response to the effect of x-radiation. Medium speed screens strike an average between these two extremes in crystal size and emulsion thickness and are average in speed. Because of a lack of speed, the slow screens are not commonly used today, although they may be used in some special applications where speed is not of paramount importance. Fast screens are rapidly being accepted in many x-ray departments today because the speed of these screens is most desirable in the interest of exposure reduction to the patient, particularly if this added speed can be had at no great sacrifice of other desirable qualities when compared to the medium speed screen. However, it is probably true that screens of medium speed are still generally preferred in a majority of x-ray departments. Comparing the speed of the three types of screens in general use today, fast screens require fifty percent less exposure than that used with medium speed screens and the slow screens require approximately three times more exposure than medium speed screens at sixty kilovolts. To be meaningful, this speed comparison must be stated at a definite kilovoltage level.

Intensification Factor

Knowing the speed of various screens makes it possible to determine the intensification factor of the screen. Intensification factor is the ratio of exposure at a specific kilovoltage without screens to the exposure at the same kilovoltage with screens to obtain the same density on a film.

Intensification Factor:

$$\frac{\text{Mas at (X) KVP without screens}}{\text{Mas at (X) with screens}}$$

Again this figure is meaningful only at a given kilovoltage level because the characteristics of calcium tungstate change noticeably as kilovoltage increases from some minimum value. Since it is very probable that radiography without screens would be limited to parts requiring no more than seventy kilovolts, the following figures approximate the intensification factor of current medium speed screens: At 50 kv—15 times; 60 kv—20 times; 70 kv—30 times.

For practical purposes, in the useful kilovoltage range, medium speed screens may be accepted as twenty to thirty times faster than a direct exposure technique when the same type film is used. Although there may be some variations, rigid quality controls during manufacture minimize the difference in speed between any two pairs of the same type of screens from the same manufacturer. It cannot be assumed that intensifying screens, similarly rated by competitive manufacturers, are necessarily of the same speed.

To appreciate the difference in the intensity of fluorescence in intensifying screens at various kilovoltage levels, place a screen beneath an x-ray tube in a darkened room and make an exposure at 70, 80, 100 kilovolts and 100 mas. Observe **through** a lead glass window and **behind** a protective barrier at a safe distance the difference in intensity of fluorescence from the screen. Do the same thing at 80 kilovolts and 100, 150 and 200 mas and note the difference.

Resolving Power

Another matter of great concern in the application of intensifying screens is the degree of sharpness of detail produced in a screen-type exposure. When direct exposure is used in radiography, each structural detail of the area examined is cast on the film by action of a single source of x-radiation — the x-ray tube. However, when intensifying screens are used, not only is the beam of x-radiation coming from the tube acting to cast a small percentage of the image on the film, but it is also activating literally thousands of other sources of light — the calcium tungstate crystals in the screen emulsion. Thus, exposure results from an interwoven pattern of light, coming from every direction above and below the film. This causes some unsharpness in detail within the image of the subject as cast on the film. In fact, unsharpness of detail, produced by the screens is the largest single contributing factor to total unsharpness in conventional radiography, with the exception of patient motion. Nevertheless, the speed of these screens is so desirable and advantageous that the unsharpness is accepted in favor of speed. Unsharpness produced with screens is a function of crystal size and emulsion thickness; the faster a screen, the greater degree of unsharpness produced with that screen. Figure 33 illustrates the action of direct exposure and screen exposure towards the production of detail sharpness.

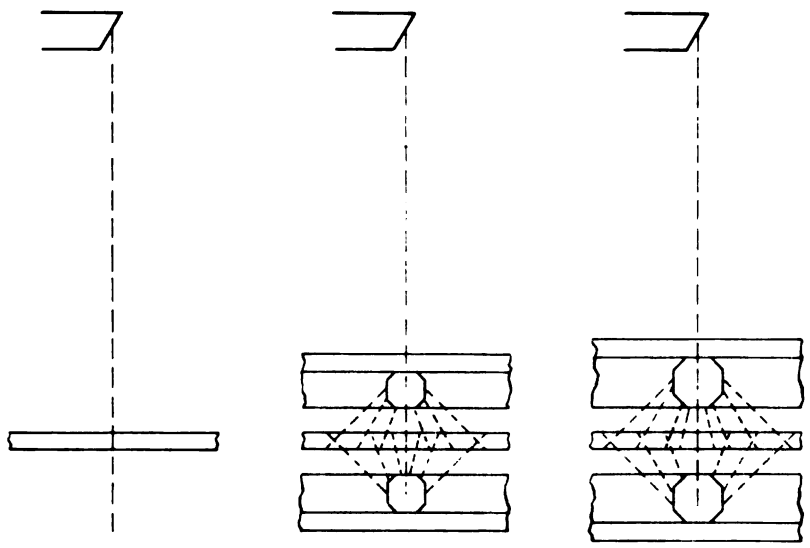


FIGURE 33. — EXPOSURE BY DIRECT RADIATION VERSUS SCREEN EXPOSURE

Resolving power of intensifying screens refers to the ability of the screens to record structural detail and may be expressed as the number of lines per linear millimeter which are clearly recorded and can be visualized on a film. For instance, if a screen is capable of resolving ten lines per millimeter, each visibly distinct line would be .05 mm. wide. Resolving power of various screens is approximately:

12 — 16 lines per mm. for slow screens

10 — 12 lines per mm. for medium screens

7 — 10 lines per mm. for fast screens

Screen Life

Economically speaking, the greatest concern about intensifying screens is their life span. Screen life is indefinite, and is a direct result of the care they receive, since intensifying screens do not deteriorate from bombardment by x-rays in the voltage ranges used in medical radiography. In other words, intensifying screens do not wear out from use but rather from abuse. It should be remembered that screens are an expensive accessory item in the x-ray department and they are one of the most fragile. Once a screen has been abused, permanent evidence of that abuse is registered as an artifact on every film exposed with that screen.

Intensifying screens do not gradually lose speed because of age or use. They do sometimes discolor, possibly as a result of chemical reaction between the emulsion and material used to mount screens in the cassette. Discoloration of the screen, from any source, will cause it to lose speed since the coloring interferes with transmission of light from screen emulsion to the film.

Intensifying screens should be cleaned periodically, but how often depends on the rate of use and the atmospheric conditions of the air in which they are used. Screens will not wear out nor develop artifacts if cleaned properly. Screen cleaning compounds prepared by screen manufacturers are available commercially. When used according to directions, these cleaners do a good job of cleaning plus the fact they may include a "static inhibitor" to retard the buildup of a static charge on the screens. Pure grain alcohol — not rubbing alcohol — may be used to clean intensifying screens. Pure, mild soap and a small amount of water with cotton sponges may be used for cleaning screens, but bear in mind that water does not evaporate as fast as alcohol or screen cleaner. Do not use too much water nor close a cassette too soon after cleaning screens with soap and water. It is good practice to lightly brush screens every day with a camel hair brush or a dry lintless cloth to remove dust particles.

FLUOROSCOPIC SCREEN

Another type of screen in an x-ray department is the fluoroscopic screen, used for direct viewing of images cast by the action of x-radiation. Fluoroscopic screens are made of an emulsion of zinc cadmium sulphide crystals in a suspension medium, spread smoothly over a suitable carrier. Zinc cadmium sulphide is used for this type screen because it fluoresces with a green-yellow light which falls within the highest sensitivity range of the dark adapted human eye. Fluoroscopic screens are not subject to handling as are intensifying screens. Since they are enclosed in a completely sealed mounting, they do not need cleaning. A word of caution about the care of fluoroscopic screens — keep them covered with an opaque covering when not in use and avoid prolonged exposure of these screens to ultra-violet rays, either from daylight or artificial sources.

PHOTO-ROENTGEN SCREEN

Screens are also used in photo-roentgen units, which are designed primarily for mass-survey radiography of chest. This type of screen is made either with a zinc sulphide emulsion for use with blue-sensitive film or zinc cadmium sulphide for use with green-sensitive film. These screens

do not require cleaning and should not be handled after placement within the light-tight hooded portion of the photo-roentgen unit.

DO'S AND DON'T'S WITH SCREENS

DON'T handle a cassette containing screens with wet hands.

DON'T blow your breath on screens to remove dust particles.

DON'T allow cassettes to remain open longer than necessary for loading and unloading with film.

DON'T handle screens or film when finger nails have been freshly painted.

DON'T dig film loose from a screen if it adheres when attempting to remove film. Stand the cassette on a hinged edge and rock it to break the film-screen adhesion and let the film fall free against the finger.

DON'T "flop and slap" or slide film between screens. Handle the film by two corners after removal of the interleaving paper and carefully place the film in the cassette. Do this as though any rough handling might cause a tremendous explosion.

DO clean screens periodically, following the manufacturer's instructions.

DO handle screens as though they are your personal property.

CONES - DIAPHRAGMS

One of the more important accessory items to be used in every radiographic exposure is a cone or some device to limit the size of the field of radiation. It is not just a matter of using a cone, but rather a matter of using a proper cone correctly. There are two rules to be kept in mind when selecting a cone or diaphragm for radiography: (1) The cone must confine the field of radiation to an area no larger than the size of film being used and preferably to the size of the area of interest on a film; (2) If a cone accomplishes its purpose, there will be a decrease in total film density, and therefore, some increase in exposure factors must be made.

A cone which permits a field of radiation at the film larger than the area of tissue to be shown on a film accomplishes nothing insofar as any improvement in film quality is concerned. Secondary radiation is produced in all tissue struck by primary radiation and if tissue is not to be included in the body area shown on a film, there is no reason for permitting that tissue to be struck by primary radiation. Secondary radiation fog arising from the tissue outside the field covered by a film, could detract from the quality of the film.

Since the total area of tissue exposed to x-radiation during an exposure is one of the factors determining the amount of secondary radiation to be produced, the following example indicates the value of using not just a cone but an effective cone. If a 14 × 17 film is exposed, using a tapered cone, eight inches in diameter at the large end, the field of radiation compared to film size is shown in A. Use a diaphragm cone and adjust the diaphragm to produce a 14 × 17 field of radiation, and B illustrates the effect. Then close the diaphragms to cut a rectangular field of radiation one-half inch smaller than the film dimensions and the result is illustrated by the dotted line in C. If A is accepted as one hundred percent of tissue exposed, then B shows a reduction of approximately forty percent in area exposed, and C shows a reduction to nearly one-half of the original area exposed. Obviously, anyone interested in reducing exposure to patients would be interested in reducing the area exposed to almost half. The radiograph in C should be acceptable because the outer half-inch of a film in both dimensions should be considered non-diagnostic. In

fact, to some radiologists, a film that does not show visible evidence of symmetrical cone-cutting is accepted as an indication that no cone was used.

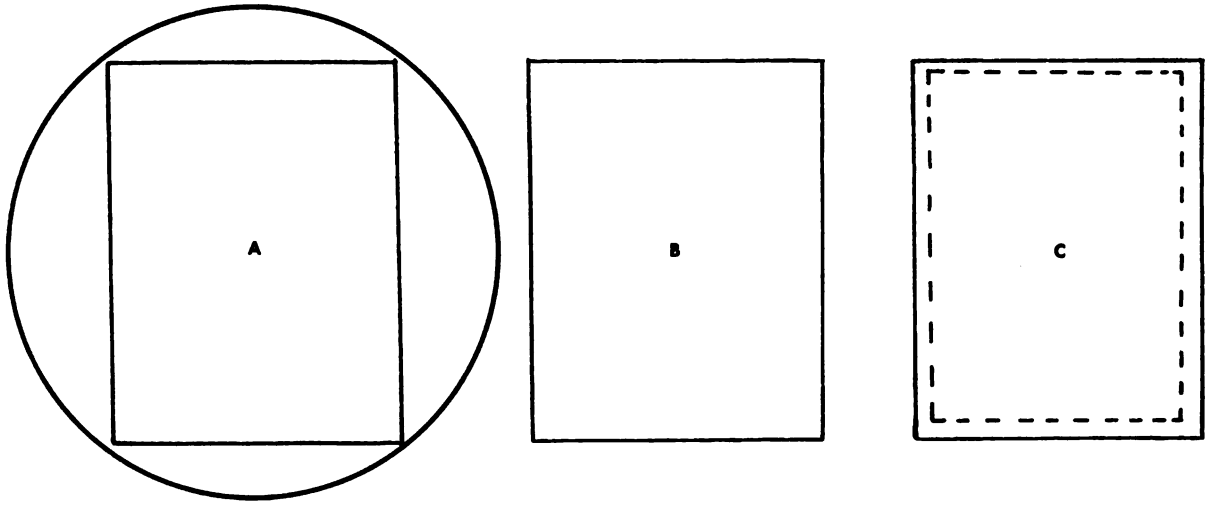


FIGURE 34. — CONING THE FIELD OF RADIATION

By conventional design, cones are tapered from a relatively small size at the base to as much as ten or twelve inches in diameter at the larger end, and by convention rather than logic, an opening in the base of these cones has generally been in a circular form. Radiographic films have always been available in a rectangular shape of specific dimensions. Geometry dictates that it is quite impossible to superimpose a circle on a rectangle without completely enclosing the circle or permitting it to extend beyond the confines of the rectangle. This is one of the reasons why diaphragms have been made with an aperture of appropriate size and shape to limit a field of radiation to the size and shape of a specific film. Such aperture diaphragms may be cut from lead, $\frac{1}{8}$ inch thick or brass $\frac{1}{4}$ inch thick and fitted into filter slots on many tube stands. Such diaphragms are particularly advantageous when fitted beneath a tube port on a unit assigned to a specific type of radiography where the same size film is used all the time and target-film distance remains constant. For example, if a unit is set up especially for chest radiography, which will be done with 14 × 17 films at a six foot target-film distance, an aperture diaphragm to confine the field of radiation at the film to a 14 × 17 size is a most efficient method of reducing the amount of secondary radiation. A formula to determine the size of aperture in such a diaphragm is:

$$\text{Size of Aperture} = \frac{\text{Size of Field in Length \& Width} \times \text{Target-Diaphragm Distance}}{\text{Target-Film Distance}}$$

A more recent development in field limiting devices has obsoleted the older, tapered cone in favor of an adjustable diaphragm-type cone, permanently attached to the tube support member of an x-ray tube carrier or stand. Such diaphragm cones provide, in one device, a means for continuous dimensional expansion of the radiation field from some minimum size to a wide-open field in either square or rectangular shape. These cones are capable of accomplishing the desired end very conveniently, but their value lies entirely in the assumption that the technician will open or close the diaphragm by means of control knobs to confine a radiation field to proper size and shape. Unless they are used in this manner, such devices serve no practical good in achieving any improvement in film quality. Such cones incorporate calibrated scales with an indicating pointer to permit adjustment of the diaphragm leaves to proper position for defining a field of radiation at a specified target-film distance.

GRIDS

A significant contribution to improved radiographic results was made by Doctor Gustav Bucky in 1913, when he invented a grid-type diaphragm to be placed between patient and film, to trap secondary radiation, and by Doctor Hollis Potter, who developed a method of moving the grid during an exposure to eliminate a pattern of the grid from appearing on the film. About 1920, the first commercially manufactured Potter-Bucky Diaphragms became available; today, such a device is considered almost an integral part of all radiographic tables. Proper terminology would indicate the Potter-Bucky Diaphragm to include a grid, its moving mechanism, a cassette tray and supporting framework for the complete device; popular usage has contracted proper terminology to the "bucky" when x-ray exposures are made with benefit of a moving grid in the table.

What is a grid? A grid may be described as a filtering device, consisting of alternate strips of lead and x-ray translucent material, placed between the patient and film to prevent secondary radiation from striking the film. Radiolucent materials used in grid construction are sometimes referred to as windows, and may be pressed paper, balsa wood, plastic, aluminum or magnesium. In fact, any material capable of providing stability with minimum absorption of useful primary radiation would serve this purpose. Because the grid is an essential accessory in a large percentage of radiography and because of the critical nature of some grids, technicians should become very familiar with the characteristics of the modern grid.

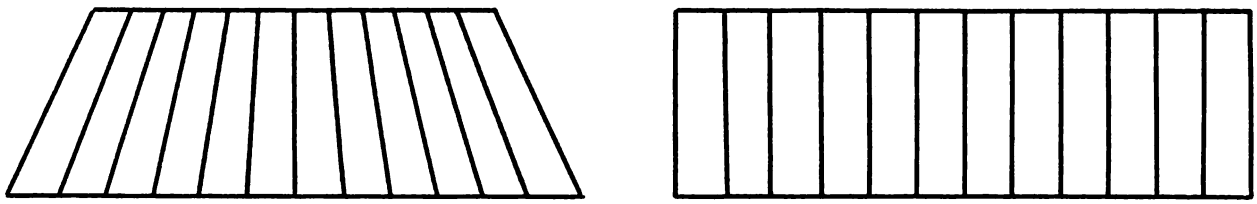


FIGURE 35. — CROSS-SECTION OF GRIDS

Grid Ratio

The ability of a grid to clean up secondary radiation is a function of the total amount of lead in the grid. Total amount of lead in a grid is determined by grid ratio and the number of lead strips per inch. For instance, a low ratio grid with many lead strips per inch and a higher ratio grid with few lead strips per inch will be practically as effective in cleaning up secondary radiation when used under the same conditions. Obviously, this statement does not apply when the lowest ratio grid is compared to the highest ratio grid.

What is meant by grid ratio? Grid ratio is the relationship between thickness of the grid and the space between two lead strips. In an 8:1 ratio grid, the grid is eight times thicker than a space between any two lead strips. This can be stated in another way. Grid ratio is the relationship between the height of a lead strip and the space between two lead strips, so that in the 8:1 ratio grid, a lead strip is eight times higher than the width of a space between it and the next lead strip in

the grid. Accordingly, a 16:1 ratio grid with 80 lines per inch is twice the thickness of an 8:1 ratio grid with the same number of lead lines.

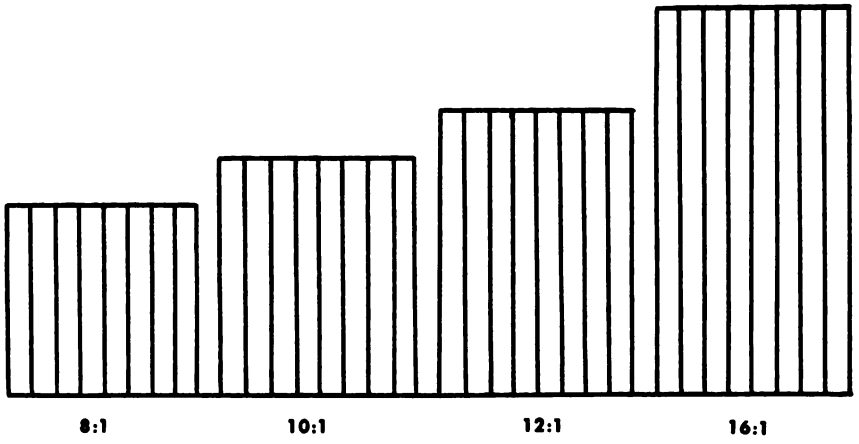


FIGURE 36. — GRID RATIO

With the knowledge that a low ratio grid with many lead strips is equally effective as a higher ratio grid with fewer lead strips per inch, a choice between two such grids for practical applications will revolve around the circumstances in which the grids will be used. Higher ratio grids are much more critical in use than low ratio grids, so if conditions are not ideal, for instance, in bedside radiography, where there is no fixed centering point and the grid-cassette combination is not likely to be level, a lower ratio grid with many lines will provide cleanup and not be as critical in application. In the radiographic table, however, where there is always a definite point for centering the tube across the table and grid, and the grid will be level, the higher ratio grid can be used with satisfactory results. The physical setup of conditions in which a grid will be used must enter into the choice of a grid — all other conditions being equal and the higher the ratio, the more critical must be target-grid centering, target-grid distance and grid level.

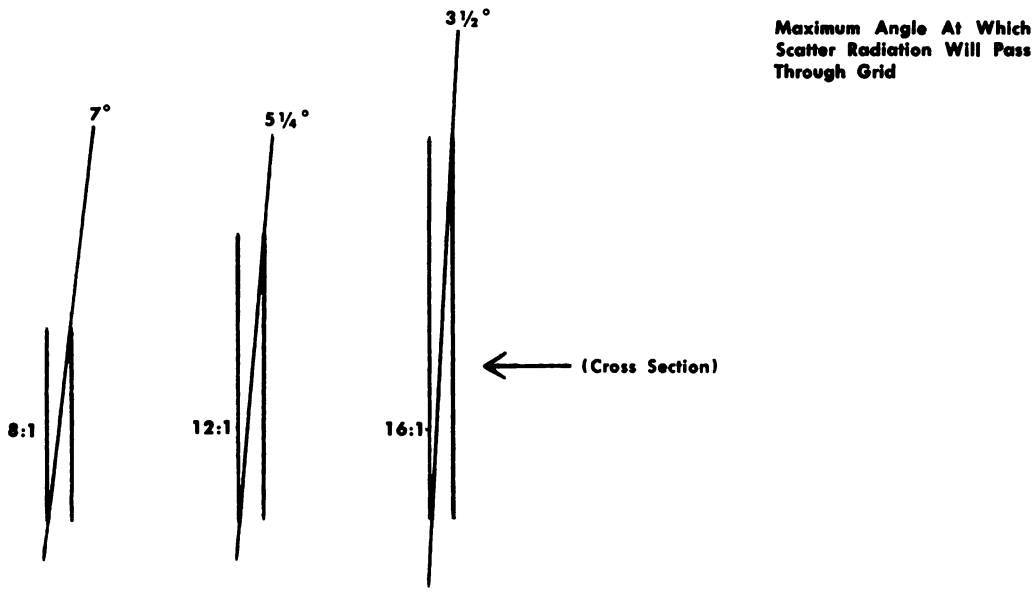


FIGURE 37. — GRID DETAILS

Parallel and Focussed Grids

Grids are either parallel or focussed. In a parallel grid, all lead strips are placed perpendicular in the assembly so that the projected lead lines would not converge at any point at any distance from the grid. This type grid permits long target-grid distance to be used, but it is critical at the shorter distances. Such a grid, used at less than a 36 inch target-grid distance will often result in evidence of cut-off or a decrease in density along the edges of a film coincident with the lateral edges of the grid.

In a focussed grid, there is some angulation in the placement of the lead strips of the grid so that these strips converge or are focussed to a definite point at some distance from the grid, this point being the x-ray tube target. Lead strips in the center section of a grid are perpendicular, but on each side of center towards the lateral edges of the grid, the strips lie at an increasingly greater angle. A focussed grid is somewhat like a segment of a wheel, with the x-ray tube target substituting for the hub of the wheel and the lead strips substituting for the spokes of the wheel. In any segment of the wheel the spokes form an angle to the perpendicular in order to converge at the hub.

The stationary-type grid may incorporate either focussed or parallel lead lines, whereas moving grids, as used in a Potter-Bucky diaphragm, are always focussed to the x-ray tube target, and the grid in this bucky is placed so that the lead strips are parallel to the length of the table.

There is another type of grid, called a criss-cross grid. This is made of two conventional grids superimposed one on the other and with the lead lines of the two grids at right angles to each other. This grid is excellent for cleanup of secondary radiation, but its applications are somewhat limited by the design. Because the grid lines of one grid are at right angles to those of the second grid, the x-ray tube must be carefully centered to the grid to avoid cut-off of radiation at the grid edges. For this same reason, the x-ray tube cannot be angled more than a few degrees to direct the central ray other than perpendicular to the grid. For the most part, a criss-cross grid is reserved for special applications where there will be no need for angling the x-ray tube and where target-grid distance and center can be fixed permanently. Angulation of the central ray 7½ degrees off perpendicular or horizontal results in almost complete cut-off of radiation to the film.

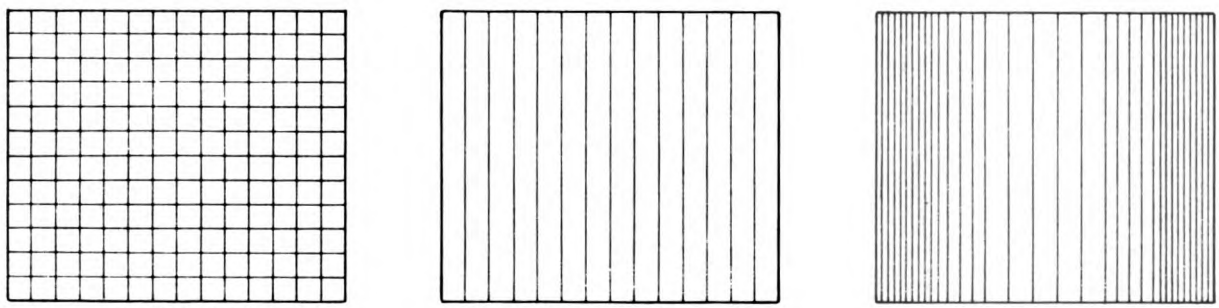


FIGURE 38. — THREE TYPES OF GRIDS (TUBE VIEW)

Grid Radius

Grid radius is defined as the tube target-to-grid distance at which most primary radiation will pass between the lead strips of the grid. Every focussed grid has a specific radius and there is minimal interference with radiation passing through the grid when it is used at the correct target-grid distance, assuming, of course, that the tube-target is centered to the grid. Deviation from the designed distance to any great extent will result in some increase in absorption of x-radiation

by the grid. The grid is out-of-focus and primary radiation strikes the lead strips instead of passing between them. While every focussed grid has a specific, designed radius, for example, forty inches, most grids permit some latitude in use from that specific distance before cutoff of radiation becomes noticeable on a film. However, because it is not possible to completely isolate the concept of grid radius from grid ratio, it will be well to remember that the higher ratio grids are considerably more critical as to radius than low ratio grids. Grids may be focussed at 30, 36, 40, 48, 60, 72 inches. Exceeding the specific grid radius does not result in a loss of film quality as quickly as use of the grid at tube-grid distances less than a recommended minimum.

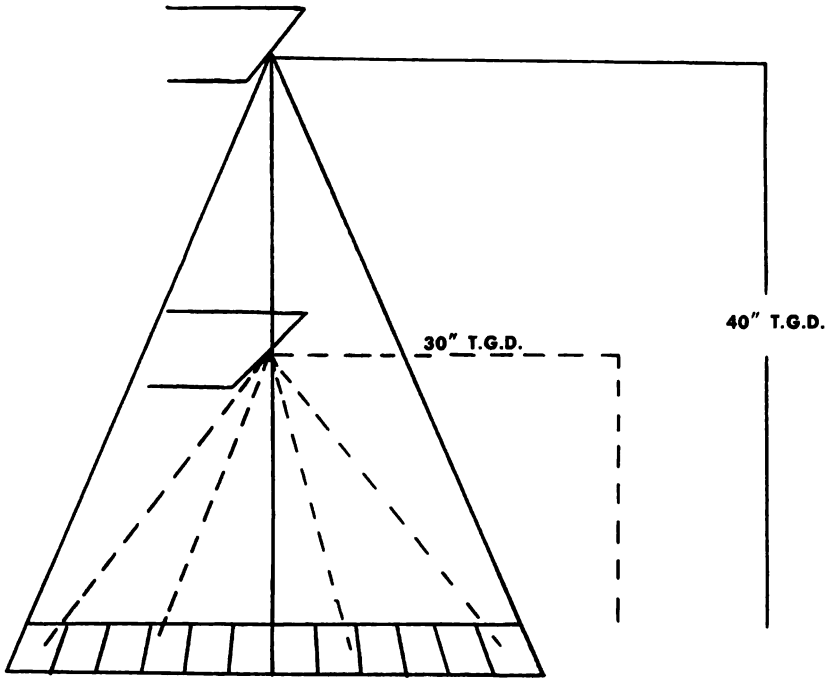


FIGURE 39. — GRID RADIUS

Lines Per Inch

Lines-per-inch, as an important factor in determining grid thickness is of concern to the grid designer. While the technician can do nothing about the lines-per-inch factor in a grid, it is of interest. Knowing the significance of lines-per-inch may aid in reaching a decision that a grid is or is not practically useful. Lines-per-inch simply means the number of lead strips per inch across the grid. For a given ratio, few lines-per-inch means that grid thickness must be increased, but for the same ratio, too many lines-per-inch results in a grid so thin that it lacks stability and may introduce some problems of support. Present design of grids seems to indicate that about one hundred lines-per-inch is a maximum useful number, and about fifty-five to sixty a minimum useful number. To maintain a given ratio and add lines-per-inch means that the thickness of each lead line must be decreased until eventually, the lead becomes so thin that it is no longer effective in stopping secondary radiation — high intensity secondary passes right through the thin lead strips of such grids. Of interest to technicians is the fact that no change in exposure factors is required for an eighty line grid in comparison to a sixty line grid when ratio and all other pertinent points are the same. Any change in film density resulting from the comparative use of two such grids is so minimal that compensation for the higher line grid is not required.

Stationary or Moving Grids

Grids will be used either as stationary or moving devices. Obviously, a pattern of the grid lines is always recorded on a film exposed through a stationary grid; the lines may be so fine and the pattern so homogenous and smooth that there is no objective detraction from quality in the film, but the very presence of the lines may create a psychological obstacle to acceptance of such films.

Radiographs exposed through a moving grid should show no evidence of grid lines when the grid is used properly. Proper use of the grid means:

1. Grid moving mechanism is energized.
2. Grid moves smoothly.
3. Rate of speed of grid travel is non-synchronous with the production of x-radiation from the x-ray tube.
4. Time of x-ray exposure is neither too short nor too long for grid travel.
5. Grid is lying flat in its support and parallel to plane of the film.
6. Tube target — grid distance is within the limits of the grid radius.
7. X-ray tube is properly centered to the grid.
8. Tube side of the grid is not facing the film.
9. Grid has not been damaged by mishandling or in manufacture.

There are probably other ways in which a pattern of grid lines can be cast on a film, so when such a problem arises, it is not solved by simply saying, "The grid doesn't work".

Grid movement may be accomplished by means of a mechanical drive which passes the grid in one direction only from rear towards the front of a radiographic table during an x-ray exposure. Such a device is known as a single stroke bucky, and in use, the technician must "cock the bucky" — prepare it for movement — and set a timer to govern speed of grid travel. Minimum time of exposure permissible with such a grid is one-twentieth second for acceptable films, and a tripping mechanism must be set to release the grid just prior to exposure and time of travel set so that the grid does not come to its rest position prior to the end of exposure. If the grid is stationary at any instant during time of exposure, a pattern of the grid will be recorded on the film. This single-stroke grid is rapidly becoming obsolete in favor of a motor-driven grid. The portable bucky still incorporates a single-stroke type of mechanism.

Automatic Bucky

The motor-driven grid, known as a RECIPROMATIC bucky, moves with a reciprocating type of motion, forward and backward across the film. Each stroke of this grid requires about one and one-quarter seconds in time, movement being initiated instantaneously before exposure and continuing as long as the motordrive is activated. Such a grid-moving mechanism need not be manually cocked, time and rate of travel are not adjustable by the technician. If an exposure time is so short, (less than one-thirtieth of a second) that inertia of the grid cannot be overcome and the grid is not moving smoothly before x-ray exposure begins, grid lines will be produced with this device.

When the grid is in the "at-rest" position, and the x-ray tube is centered across the x-ray table, the center of the grid is not coincident with the target of the x-ray tube, but is a fraction of an inch off this center towards the rear of the x-ray table. When the motor drive is activated, the grid must move that fraction of an inch so that the perpendicular center lines of the grid are coincident with the central ray from the x-ray tube before the x-ray exposure is initiated. Otherwise, the grid is off center and effectively out of focus with resultant grid line pattern and cut-off

of radiation to the film. This is the reason for establishing a minimum time of exposure when the moving bucky grid is used in radiography.

Because of this limitation on the minimum x-ray exposure time that can be used with a moving grid, there is a current tendency in radiography to use stationary grids with a very fine line pattern in exposures calling for a grid. Results are good when the proper grid is used correctly. Exposure times as short as 1/120 second become usable on procedures employing a stationary grid, something that is presently impossible with a moving grid.

Conversion Factors For Grids

The only reason for ever using a grid in radiography is the presence of an unacceptable amount of secondary radiation as made evident in the form of fog on the film. There is no single means or combination of means to eliminate all secondary radiation fog from a film. In fact, this might not be desirable for then the contrast scale in the film would be so short as to be objectionable. Approximately 85 - 90% of secondary radiation fog (dependent on the kvp used plus the volume and kind of tissue) is trapped by an efficient grid properly used. The loss in total film density resulting from this cleanup plus the absorption of some primary radiation by the grid dictates that compensation in exposure must be made to accommodate a grid where no grid was previously used. There are two methods of compensating for addition of a grid in a procedure:

1. Add twenty kilovolts to the non-grid exposure factors. The logic in this method is this — the problem is objectionable fog; the solution lies in the clean-up of fog without disturbance of an acceptable contrast scale. The grid supplies a solution to the fog problem, but it is necessary to penetrate the grid and rebuild total film density to the proper amount without any pronounced change in the contrast scale. This is accomplished by the addition of twenty kilovolts to the non-grid technic. This method assumes that the x-ray generator is capable of producing the needed additional twenty kilovolts.

2. A second method of compensating for the addition of a grid is to increase milliampere-seconds by an amount which depends on grid ratio. This is not the preferred method because a noticeable change in contrast scale of the film takes place, and in some instances, a problem of motion may be introduced because of the longer exposure time. With low power generators, it may be necessary to convert for a grid by adding milliampere-seconds rather than kilovoltage in order to stay within the rating of the generator and x-ray tube.

On the other hand, when the occasion necessitates eliminating a grid from a procedure, the problem is often one of motion by the patient. Reducing kilovolts does not permit the use of a more rapid exposure time, so a reduction of twenty kilovolts when eliminating a grid is not recommended. No speed is gained, plus the fact that a reduction of twenty kilovolts very probably will result in inadequate penetration of tissue. When a grid is eliminated from a procedure, make the technique conversion in milliampere-seconds rather than kilovolts. In this manner, the need for shorter exposure time to overcome motion is satisfied, adequate penetration is maintained and no pronounced change in contrast scale of a radiograph results.

FILTER

A filter is any material placed in the useful beam to absorb a portion of the longer wave-length, less penetrating x-ray in a beam. Usually the filters used in medical radiography, at the kilovoltages currently employed, are pieces of metal, either aluminum or copper. Filters are placed beneath the exit portal of the x-ray tube primarily for the sake of patient protection. In achieving this some additional improvement in radiographic film quality results. Every x-ray tube has filtration built in. This is known as inherent filter and consists of the glass window of the tube, oil that surrounds the tube in its casing and the plastic window in the casing. In tubes, rated for use up to one hundred kilovolts, the minimum inherent filtration is equivalent to ½ mm. aluminum; tubes rated higher than one hundred kilovolts, have inherent filtration equivalent to 1 mm. aluminum. To this inherent filtration, the National Committee on Radiation Protection and Measurements presently recommends the addition of 2 mm. aluminum filtration.

In radiography, there is a two-fold interest in the beam of x-radiation as it reaches the patient: (1) its effect on the patient; (2) its ability to cast an image of tissue on the film. As it comes from the tube target, every beam of x-radiation is heterogenous in character; that is, it is made of both long and short wave lengths with the predominant wave length being determined by the kilovoltage used. The primary purpose of filtration is to absorb a portion of the long wave length rays from the beam. Because they have little penetrating power, long wave length rays are absorbed in the patient. Those same non-penetrating wave lengths which cause concern for the patient, likewise contribute little if anything to the useful density on a film. As far as the film is concerned, the only useful radiation is that which is able to pass through the patient's body and strike the film. This is the radiation which casts an image on the film, and this radiation is basically of such short wave length that the conventional amounts of filtration absorb a minimum quantity of it. The long wave length radiation does not have enough "push" to go through the body, but does have the potential to set up secondary radiation. If this secondary radiation gets to the film, it causes a fogging effect. No grid will stop all secondary; no reasonable amount of filter at the tube will be as effective as a grid. Together they do better than either can do alone.

It is quite possible to add so much filter, in the name of patient protection, that a beam of x-radiation is not useful for radiography. The addition of filter, even the currently recommended amount, must be accompanied by a conversion of technical factors to a higher range of kilovoltage. Long wave lengths are still present at the higher kilovoltage, but as kilovoltage is increased, there is a greater predominance of shorter wave lengths which have the penetrating power to reach the film and contribute to useful density on the film. Kilovoltage values of less than fifty-five should not be used in conventional radiography of humans.

Sheets of aluminum to be used for filtering in radiography, should be secured from an x-ray supplier. This is to assure that the material is actually commercially pure aluminum #2 and not some alloy which contains metals other than aluminum but which may be sold as aluminum.

A filter, of indeterminate amount but definite effect, is discussed here under the general topic of filtration. This is the metallic filtration, which is progressively deposited over the x-ray tube window by the evaporation of copper or tungsten from the tube electrodes. Such evaporation is perfectly normal and can happen even though an x-ray tube has not been overloaded, or it may be due to several excessive exposures that were not severe enough to immediately ruin the tube. There is no method of making an intelligent estimate of the amount of this filtering medium present within the tube and its effect on film density or patient protection. It should be remembered, though, that a progressive loss of film density, when no change in technical factors or methods or materials have been made, may be due to this build-up of metallic filter over the tube window. The only remedy for this is to replace the x-ray tube.

REVIEW QUESTIONS

1. What are the criteria of a good material for cassette fronts?
2. Describe an intensifying screen and its application.
3. What is the difference between fluoresence and phosphoresence?
4. What determines the speed of intensifying screens?
5. Approximately how long will a pair of intensifying screens last? What causes them to deteriorate?
6. What effect would a pair of fluoroscopic screens have on regular x-ray film if they were used in place of intensifying screens for radiography? Why?
7. Is there more detail when screen or direct exposure is used? Why?
8. What two thoughts govern the choice of a cone in radiography?
9. Describe a bucky diaphragm. A grid.

10. What determines cleanup efficiency of a grid?
11. Define grid ratio. Radius. Of what concern is this to the technician?
12. What causes grid lines on radiographs?
13. Convert technical factors for a pelvis with an 8:1 ratio grid to use with a 12:1 ratio grid.
14. Why is the amount of filtration at the tube of concern to a technician?

ANSWERS

ANSWERS

Chapter 7

EXPOSURE FACTORS - CHARTS AND TABLES

A working combination of exposure factors is based on an ideal situation, using a given selection of physical components, x-ray generator control settings and accessory items. Ideal situations rarely exist so it becomes desirable, often necessary, to establish a new combination of exposure factors and to produce a diagnostic radiograph with other than conventional methods. In this section, charts, tables, examples are brought together to illustrate methods whereby these changes can be correctly made.

MILLIAMPERE (Ma) - TIME RELATION

Milliamperage is inversely proportional to time of exposure. This may be formulated — old ma : new ma :: new time : old time.

To solve for ma. the formula is expressed:

$$\text{new ma.} = \frac{\text{old ma.} \times \text{old time}}{\text{new time}}$$

Example: Using (X) kvp, 25 ma, 4 seconds produces a good radiograph except for evidence of patient motion. A higher ma. is required to compensate for the shorter time selected — ½ second.

Solution:

$$\text{new ma.} = \frac{25 \times 4}{.5} = \frac{100}{.5} = 200 \text{ ma.}$$

Or to solve for time, the formula would be:

$$\text{new time} = \frac{\text{old time} \times \text{old ma.}}{\text{new ma.}}$$

Example: Using (X) kvp, 100 ma, 1/10 second produces a good radiograph except for evidence of patient motion. Shorter exposure time required.

Solution:

$$\text{new time} = \frac{1/10 \times 100}{300} = \frac{10}{300} = 1/30 \text{ second}$$

Since exposure is milliamperes multiplied by time, it is apparent that the product of these two exposure factors is a constant to produce a given radiographic result. This assumes, of course, that no other factors are changed and this being the case, the term milliampere-seconds (mas) evolves in the technician's working language as a universally recognized term to express a quantity of exposure. Learn to think and express exposure factors in terms of mas.

The following chart will be useful in determining rapidly the combinations of ma. and time to produce a desired mas. If mas is known, combinations of ma. and time can be determined from the chart to produce the total mas. If mas and time are given, ma. can be determined from the chart. If mas and ma. are known, time can be found on the chart.

MILLIAMPERE - SECONDS (MaS) CHART

For 60 Cycle, Full Wave Rectified X-Ray Generators

TIME		MA											
Impulses	Seconds	10	15	20	25	30	50	100	150	200	300	400	500
1	1/120	.083	.1	.166	.208	.25	.417	.83	1.25	1.66	2.5	3.33	4.17
2	1/60	.166	.2	.274	.417	.5	.83	1.66	2.5	3.33	5.	6.66	8.33
3	1/40	.25	.4	.5	.63	.75	1.25	2.5	3.75	5.	7.5	10.	12.5
4	1/30	.333	.5	.7	.83	1.	1.67	3.33	5.	6.66	10.	13.3	16.6
6	1/20	.5	.7	1.	1.25	1.5	2.5	5.	7.5	10.	15.	20.	25.
8	1/15	.67	1.	1.3	1.67	2.	3.33	6.66	10.	13.3	20.	26.7	33.3
10	1/12	.83	1.25	1.7	2.08	2.5	4.17	8.33	12.5	16.6	25.	33.3	41.7
12	1/10	1.	1.5	2.	2.5	3.	5.	10.	15.	20.	30.	40.	50.
15	1/8	1.25	1.09	2.5	3.12	3.7	6.25	12.5	18.8	25.	37.5	50.	62.5
16	2/15	1.33	2.	2.7	3.33	4.	6.66	13.3	20.	26.7	40.	53.3	66.7
18	3/20	1.5	2.2	3.	3.75	4.5	7.5	15.	22.5	30.	45.	60.	75.
20	1/6	1.67	2.5	3.3	4.17	5.	8.33	16.6	25.	33.3	50.	66.7	83.3
24	1/5	2.	3.	4.	5.	6.	10.	20.	30.	40.	60.	80.	100.
30	5/20	2.5	3.7	5.	6.25	7.4	12.5	25.	37.5	50.	75.	100.	125.
32	4/15	2.67	4.	5.2	6.66	8.	13.3	26.7	40.	53.3	80.	106.6	133.3
36	3/10	3.	4.5	6.2	7.5	9.	15.	30.	45.	60.	90.	120.	150.
40	1/3	3.33	5.	6.6	8.33	10.	16.7	33.3	50.	66.6	100.	133.3	166.6
48	4/10	4.	6.	8.	10.	12.	20.	40.	60.	80.	120.	160.	200.
60	1/2	5.	7.5	10.	12.5	15.	25.	50.	75.	100.	150.	200.	250.
72	6/10	6.	9.	12.	15.	18.	30.	60.	90.	120.	180.	240.	300.
90	3/4	7.5	11.5	15.	18.8	22.2	37.5	75.	112.5	150.	225.	300.	375.
96	8/10	8.	12.	16.	20.	24.	40.	80.	120.	160.	240.	320.	400.
120	1	10.	15.	20.	25.	30.	50.	100.	150.	200.	300.	400.	500.

FIGURE 40.

KILOVOLTAGE - Mas RELATION

There is no fixed amount of kilovoltage to add or subtract for any given change in milliampere-seconds. The relationship between these two factors is one of percentage. There are instances in radiography where a change in the kvp-mas relationship will, for example, permit the elimination or control of motion, or permit some other desirable or necessary change in film quality. Whenever, an established kvp-mas relationship is changed, it must be kept in mind that, even though the mas are adjusted to maintain average density, an increase in kilovoltage lengthens the contrast scale, while a decrease in kilovoltage shortens the contrast scale on a film.

These charts will provide an approximately correct adjustment of kvp. when mas. is changed so as to maintain average density on a radiograph.

KVP — MAS RELATION

With Screens		Without Screens	
To Reduce mas.	Increase kvp.	To Reduce mas.	Increase kvp.
25% 50%	8% 20%	25% 50%	15% 40%
To Increase mas.	**Reduce kvp.**	**To Increase mas.**	**Reduce kvp.**
50% 100%	10% 15%	50% 100%	20% 30%

FIGURE 41.

Example:	Lateral Lumbar Spine	P.A. Chest
	kvp. — 86 mas. — 200 (100 ma. × 2 sec.)	kvp. — 80 mas. — 2½ (50 ma. × 1/20 sec.)
Problem:	Motion	Motion
Solution:	kvp. — 102 mas. — 100 (100 ma. × 1 sec.)	kvp. — 80 mas. — 2½ (150 ma. × 1/60 sec.) or kvp. — 100 mas. — 1¼ (150 ma. × 1/120 sec.)

Since there is always a very great possibility or probability that the point of inadequate penetration will be reached when kilovoltage is decreased, such a procedure is always questionable in radiography, and should be done with caution. This technique is sometimes justified on the basis of a need for a particularly short-scale contrast, for example, in soft tissue radiography. In such instances it would seem that such a special procedure would be only supplemental to conventional exposure.

MILLIAMPERE - SECONDS - DISTANCE RELATION

Radiographic density is inversely proportional to the square of target-film distance. As a general rule, it is not good technical practice to change the target-film distance conventionally used in radiography. This statement, of course, assumes that conventional target-film distance is reasonable. It is entirely possible to compensate in exposure for an increase or decrease of target-film distance, but film density is only one of the film qualities influenced by target-film distance. Accuracy in the projected image and sharpness of detail in the image on a film are likewise influenced by target-film distance. Also, when a grid is used, it must be assumed that the conventional target-film distance has been established with consideration for the radius of the grid, and a change in that distance may introduce problems involving grid focus. An original combination of exposure factors will include a reasonable target-film distance based on generator and x-ray tube capacity, tube carrier design and grid radius. Only the most demanding circumstances should

cause a change, but when such must be made, do not guess at a new milliampere-second factor and do not change kilovoltage to accommodate a change in target-film distance. Use this formula:

$$\text{new mas} = \frac{\text{old mas} \times \text{new distance}^2}{\text{old distance}^2}$$

Example: Request A.P. view of Lumbar Spine at 60″ T.F.D.

A.P. Spine	Convert to:
kvp — 70	kvp — 70
mas — 100	mas — ?
TFD — 40″	TFD — 60″
grid — 5:1	grid — 5:1

$$\frac{100 \times 60^2}{40^2} = \frac{36000}{1600} = 225 \text{ mas.}$$

Since mas. is a product of milliamperage and time, and since the request calls for 60″ T.F.D., it would be logical to use a large focal spot and high milliamperage to maintain short exposure time, for instance, 300 ma × ¾ Sec.

Request Bedside Chest Radiograph

P. A. Chest	Convert to:
kvp — 80	kvp — 80
mas — 5	mas — ?
TFD — 72″	TFD — 36″

$$\frac{5 \times 36^2}{72^2} = \frac{6480}{5184} = 1\tfrac{1}{4} \text{ mas.}$$

Again, since mas. is a product of milliamperes and time, it would be reasonable to use 150 ma. × 1/120 Sec. if a full-wave mobile x-ray unit is available and usable. If conditions restrict one to the use of a self-rectified mobile x-ray unit, 25 ma. × 1/20 Sec. or 15 ma. × 1/12 Sec. may be used.

TARGET-FILM CONVERSON TABLE

DISTANCE DESIRED (Inches)

KNOWN DISTANCE (Inches)	25	30	35	40	48	60	65	72
25	1.00	1.44	1.96	2.56	3.68	5.76	6.76	8.29
30	.69	1.00	1.36	1.77	2.56	4.00	4.70	5.73
35	.51	.74	1.00	1.31	1.88	2.94	3.45	4.23
40	.39	.56	.77	1.00	1.44	2.25	2.64	3.24
48	.27	.39	.53	.69	1.00	1.56	1.83	2.25
60	.17	.25	.34	.44	.64	1.00	1.17	1.44
65	.15	.21	.29	.38	.55	.85	1.00	1.23
72	.12	.17	.24	.31	.44	.69	.81	1.00

MULTIPLYING FACTORS

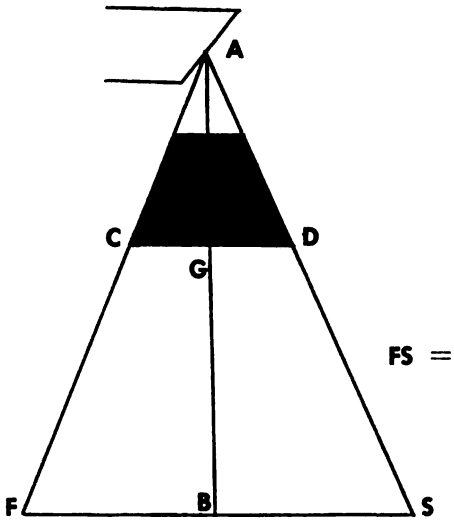
FIGURE 42.

The table in Figure 42 is a simple method of computing a change in milliampere-seconds to maintain film density when target-film distance must be changed. To apply the table, locate the known distance in the left-hand column of the table and the desired distance in the horizontal row at the top of the table. At the intersection point of these two columns is a multiplying factor. Old milliampere-seconds times this multiplier equals the new milliampere-seconds at the new target-film distance.

CONE COVERAGE

It was previously stated that a field-defining cone must confine the field of radiation to an area no larger than the size of film being used. When a flare or tapered cone is used that produces a circular field of radiation, the size of this field must be equal to or greater than the diagonal measurement of the film being exposed, if the film is to be covered by radiation. Size of field produced with various round, tapered cones may be computed by this formula:

$$\text{Size of Field} = \frac{\text{Target-Film Distance} \times \text{Lower Diameter of Cone}}{\text{Distance from Target to Lower Edge of Cone}}$$



$$FS = \frac{AB \times CD}{AG}$$

Diagonal size of most commonly used film sizes are:

5 × 7	—	8½ inches
6½ × 8½	—	10½ inches
8 × 10	—	12½ inches
10 × 12	—	15½ inches
11 × 14	—	17¾ inches
14 × 17	—	22 inches

FIGURE 43. — CONE CONVERSION FORMULA

Aperture diaphragms with rectangular opening are more effective in restricting a field of radiation to a given size film than the tapered, round cone. A formula for calculating size of aperture for such a diaphragm is:

$$\text{Aperture Opening} = \frac{\text{Size of Field in Length \& Width} \times \text{Target-Diaphragm Distance}}{\text{Target-Film Distance}}$$

To cut such a diaphragm for an 8 × 10 field of radiation at forty inch target-film distance when target-diaphragm distance is five inches:

$$\frac{8 \times 5}{40} = \frac{40}{40} = 1 \text{ inch wide aperture} \qquad \frac{10 \times 5}{40} = \frac{50}{40} = 1\tfrac{1}{4} \text{ inch long aperture}$$

Target-diaphragm distance varies in different styles of x-ray tube mounts and must be measured accurately for the specific tube mount.

CONE CONVERSION FACTORS

When a flared or tapered cone is used or a change from one size cone to a different size is made, exposure factors must be altered to compensate for the loss in total density effected by

cleanup of secondary radiation due to the cone. The table below lists an approximate change in exposure required for various cones, based on a no-cone exposure.

CONE SIZE	INCREASE Mas
8 × 10"	No Change
5 × 10"	Add 20%
3 × 10"	Add 60%
Extension Cylinder Collapsed	Add 40%
Extension Cylinder Half-Extended	Add 60%
Extension Cylinder Completely Extended	Add 100%

FIGURE 44.

When a diaphragm-type cone is used, and field size is reduced from 14 × 17 to a smaller size, an increase in exposure is required and will be approximately as follows:

FIELD SIZE		INCREASE Mas
From	To	
14 × 17	10 × 12	Add 25%
14 × 17	8 × 10	Add 40%
14 × 17	5 × 7	Add 60%

COMPARATIVE FILM SPEED

In radiography of extremities, "regular" screen film or non-screen film may be used. There is justification for either selection, so that custom often dictates the film of choice. It will be well to know the comparative speed of different type films.

COMPARATIVE FILM SPEED	
REGULAR FILM	1
FAST REGULAR FILM	3
NON-SCREEN FILM	8

FIGURE 45.

Example:

	kv	mas	
P.A. Wrist	60	40	Regular Film in Cardboard Holder
	60	13.3	
	60	5	Non-Screen Film

COMPARATIVE SCREEN SPEED

Figure 46 indicates the comparative speed of three types of intensifying screens. It is most unlikely that all three types of screens will be available for conventional radiography in an x-ray department, but there may be special procedures which, on occasion, may require the use of different speed screens than are used regularly. It should be remembered that manufacturers of inten-

sifying screens will change the speed of screens whenever this can be done with no detrimental effect on other requirements of a screen.

COMPARATIVE SPEED OF INTENSIFYING SCREENS AT 70 KVP	
Average Speed Screens	Conventional Factors
Fast Screens	Decrease mas 50%
Slow Screens	Increase mas three times

FIGURE 46.

INTENSIFICATION FACTOR OF SCREENS

Since regular film may be used with or without benefit of intensifying screens it is of interest to know the intensifying factor of screens. It has been explained that intensification factor is the ratio of exposure without screens to an exposure with screens to produce the same density on a film. The intensification factor is applicable only at a given kilovoltage. Figure 47 shows the intensification factor for medium speed screens. Again, because films and screens are continually subject to improvement by manufacturers, and as screens become faster, these figures change.

INTENSIFICATION FACTOR OF MEDIUM SPEED SCREENS			
KVP	50	60	70
Intensification Factor	15	20	30

FIGURE 47.

Example: P.A. Wrist

Direct Exposure	Screen Exposure
60 kv — 40 mas	60 kv — 2 mas

GRID CONVERSION FACTORS

It has been indicated that the addition of a grid or removal of a grid from a technical procedure requires some change in exposure factors. When adding a grid, the best method of compensating non-grid exposure is — add 20 KILOVOLTS to non-grid exposure factors. If the conversion cannot be made in this manner, the following mas. conversion factors may be used for grids of different ratios:

GRID RATIO	USE
5:1 (Plastic covered Grid)	2 × non-grid mas.
5:1 (Metal covered Grid)	3 × non-grid mas.
6:1	3 × non-grid mas.
8:1	4 × non-grid mas.
10:1	5 × non-grid mas.
12:1	5 × non-grid mas.
16:1	6 × non-grid mas.

FIGURE 48.

Example:	A.P. SHOULDER	Convert to	Or
KVP	80	100	80
MaS	2½	2½	10
GRID	None	8:1	8:1
SCREEN	Medium Speed	Medium Speed	Medium Speed

Except for a change in the contrast scale when the conversion is made by changing mas, either set of exposure factors using a grid is acceptable. However, this may not be true in radiography of the chest where involuntary motion must always be considered and exposure time kept as short as possible.

Example:	P.A. CHEST	Convert to	Or
KVP	80	80	100
MaS	10 (300 × 1/30)	40 (300 × 2/15)	10 (300 × 1/30)
TFD	72″	72″	72″
GRID	None	8:1	8:1
Field of Radiation	14 × 17	14 × 17	14 × 17
PROBLEM	Fog	Motion	None

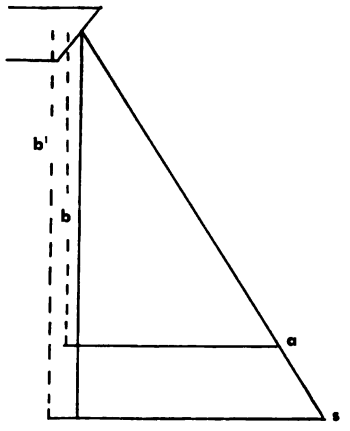
When circumstances dictate removal of a grid from a procedure where it is conventionally used, do not reduce twenty kilovolts. Convert exposure factors by using the divider instead of the multiplier in Figure 49, e.g., if an 8:1 ratio grid is removed from a procedure, use one-fourth the mas.

Example:	LATERAL SKULL	Convert to	Or
KVP	85	65	85
MaS	20	20	4
GRID	8:1	No Grid	No Grid
TFD	40″	40″	40″
Field of Radiation	10 × 12	10 × 12	8 × 10
PROBLEM	Motion	Motion and Inadequate Penetration	None

MAGNIFICATION CHART

At times, it is of interest to known the degree of magnification in the image of an object as shown on a radiograph. Magnification is influenced by object-film distance and target-film distance.

Size of an object as shown in a radiograph may be calculated by means of the following formula, based on the diagram in Figure 49.



Where:

s = size of projected image on film

a = actual size of object

b = target-object distance

b^1 = target-film distance

Then:

$$s = \frac{a \times b^1}{b}$$

FIGURE 49. — RADIOGRAPHIC MAGNIFICATION

The following table, Figure 50, gives the percentage enlargement of an object image on a film at the indicated object-film and target-film distances.

PERCENTAGE OF MAGNIFIED RADIOGRAPHIC DISTORTION
at various object-to-film and target-film distances

OBJECT-FILM DISTANCE	TARGET-FILM DISTANCE								
	24" %	36" %	48" %	60" %	72" %	84" %	96" %	108" %	120" %
1"	4.34	2.86	2.13	1.69	1.41	1.20	1.05	.93	.84
2"	9.05	5.88	4.35	3.45	2.85	2.44	2.13	1.89	1.69
3"	14.29	9.05	6.67	5.26	4.35	3.70	3.24	2.85	2.56
4"	20.00	12.50	9.05	7.14	5.88	5.00	4.35	3.85	3.45
5"	26.31	16.13	11.64	9.09	7.46	6.32	5.49	4.85	4.35
6"	33.33	20.00	14.29	11.11	9.09	7.69	6.67	5.88	5.26
7"	41.18	24.14	17.07	13.27	10.77	9.11	7.86	6.93	6.19
8"	50.00	28.57	20.00	15.38	12.49	10.53	9.09	8.00	7.14

FIGURE 50.

SOLUTION TANK CAPACITY

To assure use of a sufficient volume of concentrated solution in a volume of water to equal the recommended total volume of developer or fixer, it is advisable to compute the volume of the solution tank. Do not assume that a tank of some stated capacity will hold that volume. To compute volume in gallons, measure

$$\frac{\text{Length} \times \text{Width} \times \text{Depth} - 1 \text{ inch (ledge for suspending hangers)}}{231 \text{ (cu. inches in gallon)}}$$

TEMPERATURE CONVERSION

To convert Fahrenheit to Centigrade, subtract 32° and multiply by 5/9; to convert Centigrade to Fahrenheit, multiply by 9/5 and add 32°.

HIGH SPEED PROCESSING

Radiographic procedures, carried out during surgery usually demand speed for the entire procedure, including viewing of the film. Nevertheless, good quality films are required and expected in surgery as they are under conventional circumstances. Good quality radiographs never have been produced by over-exposure and sight development, and during surgery, is certainly not the time to attempt to work out such a system.

When it is imperative that a radiograph be seen quickly after exposure, a better system is to prepare a tank of high speed liquid developer, raise the temperature to 90° F. Use an acid stop-bath and fresh fixer, maintained at a temperature within three to five degrees of the developer temperature.

After a conventional exposure for the part being radiographed, develop film for thirty seconds, place in stop-bath for three seconds, then in fixer till cleared; rinse film briefly and present for viewing. After film has been inspected, return it to the regular fixer for conventional fixing and then wash film in the usual manner.

Do not overexpose the film to be processed in this manner. A technician cannot work fast enough with an overexposed film and hot, high intensity developer to avoid excessive density on the film.

SPINNING TOP TEST OF TIMER

Short exposure times are only as accurate and reproducable as the timer is accurate. An exposure time of longer than one-quarter second will tolerate some degree of error in the timer, assuming there is latitude built into the combination of exposure factors.

To test a timer for accuracy at fractional-second times, a simple method employs a metal top, in the shape of a disc, with a small hole or slot drilled near the periphery of the disc. If full-wave, sixty cycle, alternating current is used in the x-ray unit, there are 120 impulses of x-ray per second of exposure. In 1/120 second there is 1 impulse; 1/40 second, 3 impulses: 1/10 second, 12 impulses, and so on. Timer accuracy becomes more significant as shorter exposure times are used. For example, if a timer is set for 1/40 second, but delivers only 2 impulses of x-radiation rather than the expected 3 impulses, one-third of the exposure is lost and density will be one-third less than it should be. Such a loss of density in the film is visible to the unaided eye. Or an x-ray generator can appear to be very efficient if the timer delivers two instead of one impulse of x-ray when it is set for 1/120 second exposure.

To make a timer test, set the timer for the desired fractional-second exposure time. Use 60 kvp, 40 inch T.F.D., and use intensifying screens. Divide a film into sections so that several indentically timed exposures can be made on the same film. After exposure, process the film in a conventional manner and count the number of black dots around the periphery of the circle cast by the spinning top. If the timer is accurate, the number of dots should total the correct number of impulses of x-radiation as previously explained.

When the timer on a self-rectified generator is tested, the number of dots will be halved in comparison to a full-wave generator — 1/10 second =6 dots; 1/30 second = 2 dots — since every other impulse of current is suppressed by the x-ray tube.

The spinning top test may be used to determine that one or more valve tubes are not functioning in a full-wave rectified system. You will recall that failure of a valve tube to rectify the inverse half cycle of current means that the x-ray tube itself must suppress that half cycle. The output then becomes effectively the same as for self-rectification, and the number of dots would be as for a self-rectified unit.

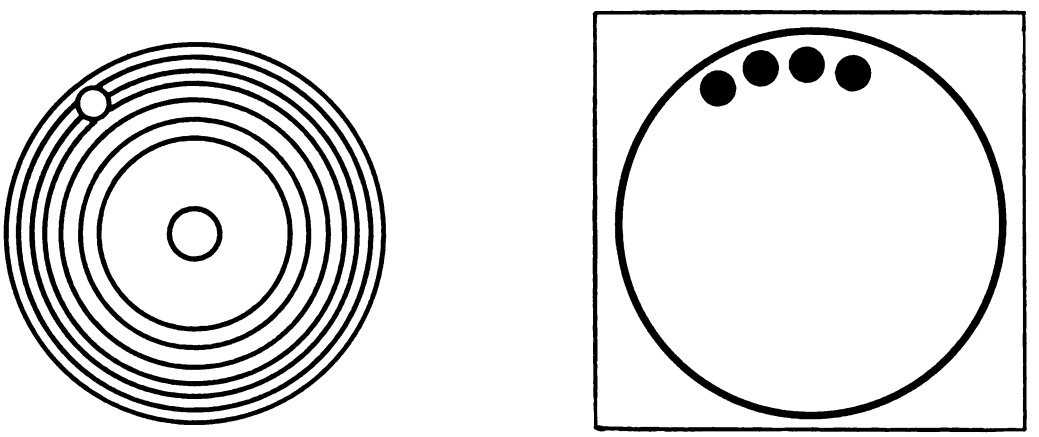


FIGURE 51. — SPINNING TOP AND 1/30 SECOND TEST FILM

RADIATION DOSAGE

In recent years, there has developed more than usual concern about the exposure of man to radiation. While there are reasons for such concern, the reasons should temper one's actions with logic rather than panic. Competent authorities in the field have made intelligent studies of the

problems involved in providing protection to man from the several sources of radiation to which he is or may be exposed, and, on the basis of these studies, have made recommendations that should guide those who use x-radiation on humans during the course of a medical x-ray examination.

It would seem that two thoughts should serve to guide x-ray technicians in this respect. One involves an obligation, the other involves a right. As for the obligation, if a patient is accepted for radiographic examination, everyone concerned in the accomplishment of the examination assumes an obligation to make certain the patient is given the best examination possible. When this obligation is assumed, there follows the right to expose the patient to x-radiation. Such a right immediately imposes another obligation to the effect that, "there is an obligation on the part of all who use radiation to subject the patient to as small a dose as is consistent with an adequate examination. Anything that can be done to reduce the dose will be a step in the right direction." (Trout et al: See Bibliography #8).

Technicians have at their disposal, numerous methods of reducing radiation dose to the patient without disturbing film quality. Two methods often overlooked are the use of filters and the use of higher kilovoltage (and higher kilovoltage does not necessarily indicate values above one hundred kilovolts for all radiography).

As visual evidence of the value of filtration and higher kilovoltage, in reducing radiation to the patient the chart in Figure 52 may be used. It is emphasized that this chart applies only to the one x-ray unit, and the conditions under which the chart was prepared, and that, while the figures may be a close approximation, they do not apply specifically to any other x-ray unit. A table prepared under actual operating conditions, by competent personnel, should be prepared for a specific x-ray unit if greater accuracy is desired.

*** RADIATION INTENSITY USING A HIGH VOLTAGE ROTATING ANODE TUBE**

Added Filter	KVP	50	60	70	85	100	130	
None		7.6	10.2	13.3	18.4	22.5	29.6	mr/mas @ 40" F.S.D.
0.5 mm Al.		4.8	6.8	9.2	13.2	15.8	20.4	
1.0 mm Al.		3.2	4.6	6.3	9.6	12.0	15.9	
2.0 mm Al.		1.5	2.2	3.2	5.3	8.0	11.3	
3.0 mm Al.					3.1	5.8	9.2	

RADIATION INTENSITY USING A STATIONARY ANODE TUBE

Added Filter	KVP	50	60	70	85	100	
None		8.2	11.6	14.9	19.8	25.0	mr/mas @ 40" F.S.D.
0.5 mm Al.		5.0	7.4	9.8	14.0	17.0	
1.0 mm Al.		3.3	4.8	6.7	10.0	12.8	
2.0 mm Al.		1.5	2.3	3.4	5.6	8.4	
3.0 mm Al.					3.2	5.8	

MULTIPLYING FACTORS TO DETERMINE RADIATION INTENSITY AT DISTANCES OTHER THAN 40"

F. S. D.	35"	34"	33"	32"	31"	30"	29"	28"	27"	26"	25"
Multiplying Factor	1.30	1.38	1.47	1.56	1.72	1.78	1.9	2.04	2.19	2.37	2.56
F. S. D.	24"	23"	22"	21"	20"	19"	18"	17"	16"	15"	
Multiplying Factor	2.78	3.02	3.31	3.63	4.0	4.44	4.94	5.87	6.25	7.1	

NOTE: The inverse square law can be used within practical limits to calculate intensity at other distances.
*** Trout et al. See Bibliography #8.**

FIGURE 52.

To apply the chart, note first that the intensity figures in the table are based on a 40″ F.S.D. (focal-skin distance). Therefore, it is necessary to measure thickness of the body part in centimeters, reduce to inches (2.54 cms. per inch) and subtract the figure from 40. Across the bottom of the chart are multiplying factors to be used at focal-skin distances other than 40 inches. Locate the added filter at left side of the appropriate table and in the KVP column read the mr/mas figure. Multiply this by the multiplying factor to correct for focal-skin distances other than 40 inches. Multiply this figure by the mas used for the exposure to determine total mr. Divide this total by 1000 (1000 mr = 1 r) to arrive at number of r per exposure.

Example: **Abdomen 25 cm. (10″), Exposures Made With Rotating Anode Tube**

KVP — 70	KVP — 70	KVP — 85
MaS — 50	MaS — 50	MaS — 25
TFD — 40″	TFD — 40″	TFD — 40″
FSD — 30″	FSD — 30″	FSD — 30″
No Added Filter	2mm. Added Al.	2 mm. Added Al.
1.2 r	.3 r	.25 r

NOTE: All fractions rounded off to next high full number for ease of computation.

REVIEW QUESTIONS

1. What is the relation of kvp, ma, mas, time to radiographic density?
2. What is the relation of ma to time of exposure?
3. How much kvp is added when time of exposure is halved, using intensifying screens? Mas is reduced 50% and kvp is increased .....with screens? ..... with direct exposure?
4. What is the relation between time of exposure and target-film distance?
5. What formula is used to determine size of field to be covered by a cone?
6. What change in exposure is required when a fully extended extension cylinder is used in place of a 5″ cone? Why?
7. What is the comparative speed of fast regular film to non-screen film?
8. How much faster are fast screens than medium speed screens? At any kilovoltage?
9. What ratio grids are in use in your department and what is the conversion factor for the grids?
10. How many gallons of solution does the developer insert tank in your darkroom hold? The fixer tank?
11. Describe a method of rapid processing usable in surgical radiography?
12. How would you test a timer for accuracy at 1/40 second?
13. Suppose a timer delivers 8 impulses of x-ray at 1/15 second with a full-wave generator, is it accurate?
14. How many 'dots' on a timer test film with a 15 ma self-rectified bedside unit at 1/12 second?
15. What combinations of ma between 10 and 100 and time between 1/120 and 1/5 second will produce 1.66 mas?

ANSWERS

ANSWERS

ANSWERS

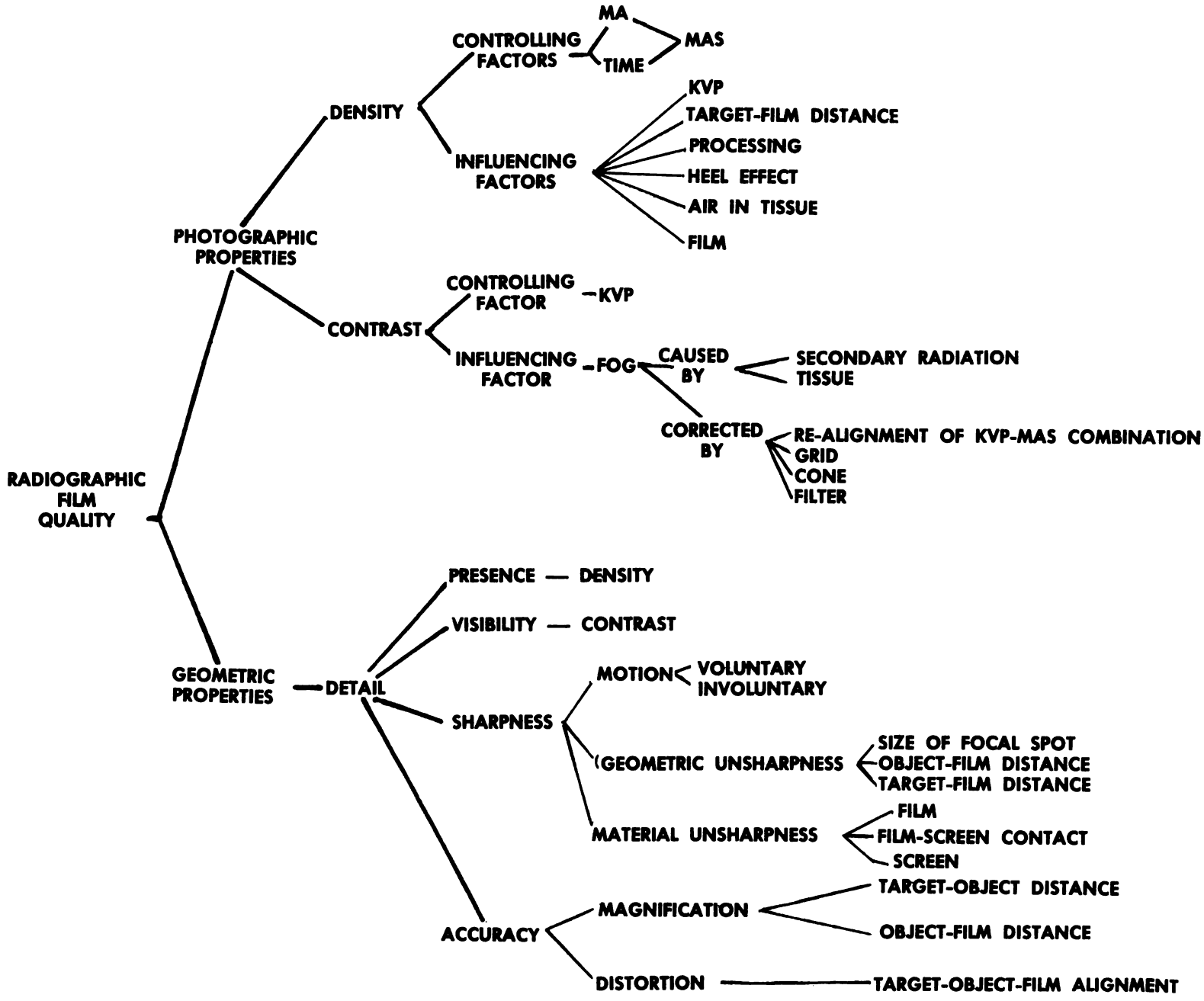


FIGURE 53. — RADIOGRAPHIC FILM QUALITY

Chapter 8

RADIOGRAPHIC FILM QUALITY

Every patient, referred to the x-ray department for radiography, constitutes a diagnostic medical problem, insoluble without the benefit of x-ray examination, or at least in need of this examination as a confirmatory measure. The collective talents of the x-ray department, technical and medical, and its facilities are being enlisted to solve this problem. The radiologist, who, ultimately must solve the diagnostic problem, must base his decision to a large degree on what he sees in a radiograph, and what he sees, will depend on the quality of radiograph produced by the technician. This is the reason the technician is so important; this is the reason a radiograph must be the best film it is possible to produce, and this is the reason a radiograph must be diagnostic. Just any old film is not diagnostic. If this were true, all the vast improvements in equipment, in films, in methods, all the time and energy spent by many people in the x-ray field in the past sixty-five years, has been to no avail. Roentgen's basic equipment did record images of objects on a medium, but with all due respect to him, those images would hardly be accepted as diagnostic today. The only justification for an x-ray technician, as such, is a desire, a willingness, an ability to produce diagnostic radiographs.

To be classed as diagnostic, a radiograph must possess certain qualities. The technician must know what these qualities are, not just the names; they must know how these qualities are produced, when quality is not the best, and what is most important, technicians must acquire an ability to rectify improper quality. Quality is an objective fact; it is not something subject to an individual's likes and dislikes. Quality is in the radiograph. It is unfortunate that, through the years, the interpretation of quality has become a subjective thing. Radiologists, in many instances, accept a film for interpretation, only because they believe the technician is honest enough to do the best job possible. The technician subjects the radiologist to the chance of missing a diagnosis every time a film is turned in for interpretation in spite of its inferior quality. This may not seem important now, but it could be mighty important if you were the patient.

What is a diagnostic radiograph? It may be defined as the radiograph in which there is sufficient density to show an image of tissue that is adequately penetrated, sharply defined, and in which the variations in tissue opacity are sufficiently evident. If that definition is analyzed, it becomes apparent that the diagnostic radiograph must meet some rigid specifications. **Sufficient density** is one amount; any less than that amount means that some of the structural details will not be seen on the film; any more than that amount means that some details will be hidden by excess density. **Image of Tissue** — in radiography, we are interested in images, not silhouettes of tissue, because only an image can reveal structural details of the patient. **Adequately penetrated** — adequate penetration is basic to the production of a radiographic image, and no reasonable amount of radiation can compensate for a lack of penetration. **Sharply defined** — unless the image of the tissue is sharply defined, the condition of the tissue may be impossible to define. **Variations in tissue opacity sufficiently evident** — unless the various types of tissue that constitute a body part can be differentiated one from the other, unless disease and non-diseased tissue can be distinguished, the radiograph has not served the purpose for which it was taken.

It must be obvious that the production of a diagnostic radiograph involves the solution of many problems, some of which are concerned with photographic quality of the image, and others are concerned with the geometric quality of the image. A diagram of radiographic film quality,

Figure 53, and a study of what goes into the production of a diagnostic radiograph should reveal the many problems. A discussion of each quality should help to find the solution to these problems. The photographic problems in radiography offer, perhaps, the greatest area for variation from the ideal, and the greatest possibility for commission of human errors. The same latitude for error is not true when considering the geometric formation of the image. This is largely a matter of establishing a series of correct angles between the source of x-radiation, the object and the recording medium. Since geometry is the exact science it is, there is only one method to cast a geometrically accurate image of an object on a film with neecssary sharpness of detail in the image. Deviation from that method means that the resulting image will show something more than the least magnification and distortion, and something less than the sharpest definition. The radiograph may still be diagnostic because it is not necessary to produce sharpest definition and least distortion and magnification, as will be indicated later.

RADIOGRAPHIC FILM DENSITY

To appreciate radiographic film quality, properties are defined and their controlling and influencing factors analyzed. What is radiographic density? Radiographic density is defined as the deposit of "black, metallic silver which remains on a film after exposure and processing". What is proper density? Proper density is the amount which makes the structural details within the image of an object readily visible. As previously stated, proper density is a specific amount. A lack of or excessive density means that some structural details will not be visible. In the production and maintenance of density, there are controlling factors — controlling factors being those which are manipulated when a predictable change in film density is necessary. There are also influencing or affecting factors. Manipulation of these factors will produce a change in film density, but not in a predictable amount, and a change in density will be only one of several changes in film quality which may result.

Controlling factors for the production and/or maintenance of density are: (1) milliamperage; (2) time of exposure. What is the relationship of milliamperage to density? It is a direct relationship — density is directly proportional to milliamperage or a change in milliamperage. This is true in the range of useful radiographic density and up to the point of blackness on a film. When complete blackness is produced — total density — all silver bromide has been reduced to metallic silver and regardless of the amount of additional exposure, no more silver or density can be added to the film. Due to the current design of x-ray controls which incorporate pre-determined selec-

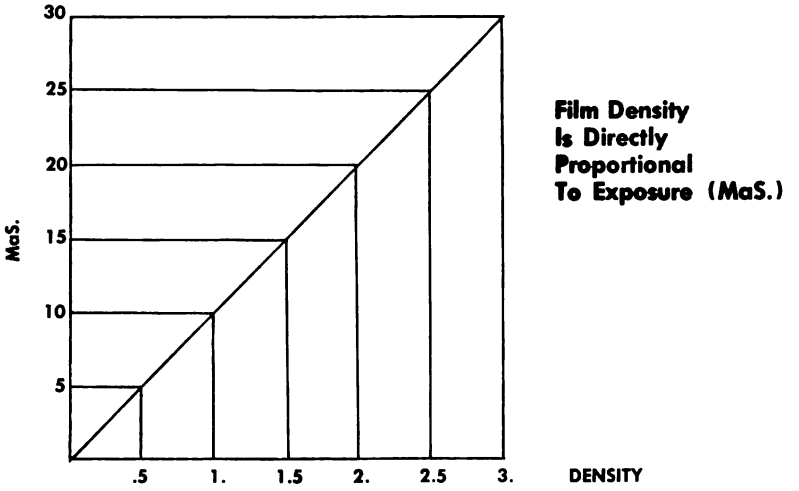


FIGURE 54.

tion of milliamperage, it is not always convenient to use milliamperage as a variable factor in the production and maintenance of density. One other factor — time of exposure — bears the same direct relationship to density as milliamperage. Therefore, time can be used to produce and control predictable changes in density. Since either, or both, milliamperage or time bear the same relationship to density, and since the product of the two equals milliampere-seconds, then milliampere-seconds (mas) becomes the controlling factor in the production of density, with time as the preferred variable.

How is radiographic density determined or measured? The amount of density is determined by the amount of light transmitted through a film from a standard light source. This amount of light can be accurately measured by means of a densitometer or light measuring instrument, but such a critical determination is not normally used in medical radiography. Photographically speaking, a radiograph is analyzed in two ways, the total deposit of silver and the distribution of that silver throughout the image on the film. The deposit of silver is density. Then, the first thought that should come to mind when inspecting a radiograph for proper density should be, "Is there enough or is there too much density?" If, on inspection, the immediate reaction is that the film does not have enough density, then double the milliampere-seconds; if the immediate decision is that the film has too much density, then halve the milliampere-seconds. This decision can be immediate, based on the reaction upon viewing the film. If a first inspection indicates a need for a slight change in density, but not to the extent of doubling or halving density, then make at least a thirty percent plus or minus change in the original exposure. It takes at least a thirty percent change in exposure to make a visible change in radiographic density. Experience is the only teacher that can develop an ability to judge the amount of change in exposure necessary to rectify a faulty first exposure.

Radiographic density is the most important of all qualities in the film; it is basic to a diagnostic radiograph. Obviously, the worth of any and all other film qualities is dependent on the presence of a complete image of the object under study. Remember that proper density is the amount which makes the structural details within the image of an object visible, and that this is an objective not a subjective decision. Remember, too, that milliampere-seconds, with time as the variable, is the only factor in radiography that will permit predictable changes to be made in density. Milliampere-seconds is the factor of quantity.

The influencing factors in the production and maintenance of density do produce changes in density but not in a predictable manner. Very often, the manipulation of one or other of these factors upsets density completely, and then it become necessary to manipulate the controlling factor to obtain proper density. How do the influencing factors affect radiograph film density.

KILOVOLTAGE changes density but in an unpredictable manner. The effect of kilovoltage on density comes about in two ways. Kilovoltage determines wavelength of x-radiation; higher kilovoltage means shorter wavelength and shorter wavelength indicates more penetrating power; more penetrating power means more radiation to the film, and therefore more density. But this effect varies, and is dependent on the range of kilovoltage being used. In the lower kilovoltage range, only a small change in kilovoltage is necessary to make a slight change in film density. However, as a basic kilovoltage is increased to some higher level, the amount of kilovoltage necessary to make a slight change in film density becomes greater. The kilovoltage changes mentioned do not double or halve density; they bring about only enough change in density to be visible. Nobody knows how much change in kilovoltage is necessary to double or halve film density, and have only that effect take place.

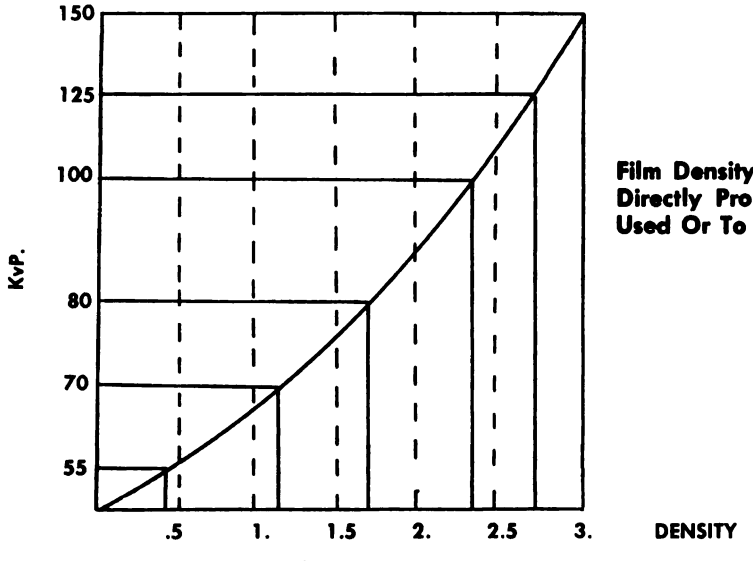
A second way in which kilovoltage influences density is due to the fact that kilovoltage is one of the factors largely responsible for the amount of secondary radiation fog. Fog is density, undesirable, but nevertheless, it is density. As kilovoltage is increased, fog increases but in an indeterminate amount, and perhaps to the extent that the means for controlling secondary radiation fog at higher kilovoltages may not be available.

AT	ADD
40 kvp	2 kvp
50 kvp	3 kvp
60 kvp	3 kvp
70 kvp	4 kvp
80 kvp	4 kvp
90 kvp	5 kvp
100 kvp	5 kvp
110 kvp	6 kvp
120 kvp	8 kvp
130 kvp	10 kvp
140 kvp	10 kvp

APPROXIMATE KILOVOLTS TO BE ADDED AT VARIOUS LEVELS TO PRODUCE A NOTICEABLE CHANGE IN FILM DENSITY.

FIGURE 55.

Kilovoltage determines penetration and a kilovoltage that penetrates an average amount of normal tissue without the production of uncontrollable fog should not be changed in order to change density on the film. From this point on, any change in density on a film, required by a change in circumstances, such as a change in volume of tissue or a change in normality of tissue, should be brought about by changes in the factor that will result in a predictable and desired change in density.



Film Density Is Not Directly Proportional To KvP. Used Or To A Change in KvP.

FIGURE 56.

Another reason for not changing kilovoltage to control density is the fact that every x-ray generator is rated at a maximum kilovoltage, and when that maximum is reached, there is no more kilovoltage available. It is reasonable to assume that a greater volume and/or opacity of tissue absorbs a greater quantity of radiation, and therefore, as tissue volume is increased, kilovoltage should be increased to maintain density. If the kilovoltage is to be the variable factor to control density, then there should be an unlimited number of kilovolts available from the transformer to

assure proper density when even the largest volume of tissue is radiographed. It is confusing and not quite logical to use kilovoltage up to a certain point to control density and then to change to some other factor because there is no more kilovoltage available from the transformer.

After kilovoltage has provided penetration, it can be manipulated in conjunction with a compensating change in milliampere-seconds to produce any necessary change in the contrast scale of a radiograph. Kilovoltage is the factor of quality in a beam of x-radiation. It indicates the kind of radiation, long or short wave length, but it does not indicate any specific quantity of radiation.

TARGET-FILM DISTANCE influences radiographic film density and changes in target-film distance will produce changes in density in accordance with the inverse square law. However, there is a maximum and minimum usable target-film distance, governed by the design of equipment and common sense. Too, target-film distance has a direct influence on sharpness of detail and accuracy in the projected image of an object, so if by manipulating target-film distance, a problem in density is corrected only to introduce a problem in sharpness or distortion, no progress has been made.

PROCESSING of a film influences density because radiographic density is the deposit of black metallic silver which remains on a film after exposure and processing. With two variables, exposure and processing, it is quite difficult if not impossible to solve a problem in radiographic density. The effect of exposure changes on film density is a known, definite thing; the effect of changes in processing is known but not definite. With two possible variables, it is only logical that one of them be fixed but permit the other to remain variable to provide a means of controlling density. Since the effect of exposure changes are known and definite, the films must be processed on a strict time and temperature basis or uncontrollable, unpredictable and non-repetitive changes in density will occur.

HEEL EFFECT influences density because of the variation in quantity of x-radiation over a large area. As explained previously a technician must be conscious of the heel effect whenever radiography is done at a relatively short target-film distance, and take the necessary steps to prevent the variation in film density resulting from this phenomenon. Certainly, though, the heel effect cannot be used to make a predictable, controlled change in radiographic density.

AIR IN TISSUE makes that tissue more easily penetrated. In radiography of body areas where the quantity of air in tissue can vary, dependent on the patient, some effort must be made to make sure that approximately the same volume of air is in that tissue every time it is radiographed. In radiography of the chest, "Take in a deep breath", does not necessarily mean the same thing to all patients; to some, a little gasp of air is a deep breath, to others the same instruction is an invitation to attempt to create a vacuum in the room. Even though the thickness and condition of tissue is the same in two patients, film density will vary because of the difference in air content in the lungs. When a radiograph of the chest is unexplainably lacking in density, count the number of ribs above the diaphragm as shown on the film. An average, normal patient will push the diaphragm down between the tenth and eleventh rib on full inhalation. If inspection of the film does not indicate full inhalation, instruct the patient as to what is expected of him rather than change exposure factors for a second radiograph. The same effect is seen in radiography of a lateral view of the thoracic spine when density on a film is quite dependent on the amount of air in the lung tissue superimposed over the spine. This is one of the reasons why an exposure of this part is more satisfactory when the patient continues to breathe normally during the exposure rather than to suspend respiration on inhalation or exhalation. In this instance, milliampere-seconds should be so arranged that an exposure time of four to five seconds or longer is used. In that time the patient goes through several breathing cycles, and there is an average amount of air in the lungs, so that film density, with a proper exposure, will be balanced throughout the area of the image. A restraining band across the shoulders minimizes the possibility of motion by the patient even in such a long exposure.

In general, respiration should be suspended only when the breathing action will result in loss of detail sharpness in a radiographic image. In those body parts not involved in the breathing action, permit the patient to breathe, and use restraining devices for immobilizing the patient. When instructing a patient to, "Take in a deep breath" for chest radiography, it is most essential to give the patient time to breathe deeply and a chance to stop breathing before the exposure switch is closed.

FILMS of different manufacturers do not all contain the same amount of silver and consequently they will not all produce identical densities when exposed to x-radiation and processed. Obviously, correct exposure factors can be established for the use of any film, for no manufacturer will long be in business if his product will not function properly. The important thing is to select a film, develop exposure factors for that film, learn its peculiarities, how it responds to x-radiation and how it behaves in the developer, and then continue to use that film until it seems advisable to select a different film and to re-establish the routine. There are enough variables in radiography without introducing a film variable, so it is not good technical practice to mix brands of film in the department.

Insofar as the production and maintenance of radiographic film density is concerned, those seven factors must be considered and correctly selected to produce proper density. At the same time, it is quite obvious that other things enter into the overall picture of density. But, a technical procedure is built on the basis of using screen or direct exposure, grid or no grid, a cone of some type, and all these incidentals are taken into consideration when a basic exposure is established. When circumstances dictate that the basic exposure needs altering in order to maintain density, these incidentals will not be changed. The factor that controls density will be changed.

RADIOGRAPHIC CONTRAST

The second photographic property of a radiograph is contrast. Density and contrast are described as two different radiographic qualities, and yet it may be difficult to strictly divide the two, since after all, contrast is nothing more than a variation in degrees of density. It may be stated that radiographic contrast is the difference in density between two selected areas of a radiograph. Density and contrast are described as contrary not contradictory qualities.

What is radiographic contrast? It is defined as the difference in density levels or tones of the radiograph, resulting from the distribution of silver over the entire image. If density is a deposit of silver on the film, then the amount of silver deposit is dependent on the amount of radiation which has penetrated the patient, so that contrast is likened to an absorption pattern of the various opacities within the patient. If a body part of homogenous thickness and opacity were x-rayed, the radiograph would exhibit no contrast since the same quantity of x-radiation would be absorbed throughout all the tissue and the same amount transmitted to the film. Therefore, there would be only one density demonstrated on the film; at least two density levels must be present before contrast exists. It is the difference in absorption characteristics of the various tissues in any body part that causes a difference in x-radiation transmitted to the film, resulting in contrast. It can be no more simply stated than — Density is the deposit of silver; Contrast is the distribution of that silver.

A scale of contrast is determined by the difference or the scale of gradation between a minimum and maximum useful density on the film. Short scale contrast indicates that the graduation of density tones is abrupt, there is a sharp difference between the least and most dense areas with little toning between these extremes. Long scale contrast indicates that the gradation of density tones is extended, and there are many shades of density between a minimum and maximum in the image. As a rule, radiographs with a short scale contrast are of questionable diagnostic value. Any clear area on the film indicates there is no silver on the film and no silver indicates no radiation to that portion of the film, and no radiation to the film indicates no penetration of the patient. There

can be no image without penetration of the patient. Radiographs with a short scale contrast will reveal little if any structural details in the areas of more opaque tissue, and in areas of little tissue opacity, there is excessive density with detail structure not readily visible. The ideal, of course, is adequate penetration of all opacities of tissue in the body area, with an evenly graduated density from minimum to maximum.

Short scale contrast is often called "high contrast" while long scale and "low contrast" are often used synonymously. The terms, high or low contrast, are not definitive of the situation, and in the interest of accuracy learn to describe contrast in a radiograph as short scale or long scale. These terms and their meaning are universally understood.

KILOVOLTAGE is the controlling factor in the production and maintenance of contrast. Lower kilovoltage produces longer wavelength x-rays, not so penetrating, and therefore is productive of short scale contrast. Higher kilovoltage, with an accompanying shorter wavelength, produces a more penetrating x-radiation and hence, produces a longer contrast scale. What is the proper scale of contrast? Proper contrast scale is that which makes the variations in tissue opacity sufficiently evident. Proper contrast scale, like proper density, is an objective property of the radiograph because it either is or is not present and is not dependent on one's regard for contrast. Short scale contrast in radiography has much more eye appeal than long scale contrast. In medical radiography, the prime objective is the production of diagnostic radiographs, not eye-appealing pictures.

In the production of proper contrast, kilovoltage is the controlling factor, but a change in kilovoltage alone does not solve the problem when a shortening or lengthening of a contrast scale is necessary. If kilovoltage alone is changed, density is altered. A change in kilovoltage, in favor of a different scale of contrast, must be accompanied by a compensating change in milliampere-seconds to off set the effect on density. Proper contrast indicates a balance between kilovolts and milliampere-seconds, so when a change in contrast scale is required but without disturbing average density on the radiograph, both kilovoltage and milliampere-seconds must be altered to maintain that balance.

Contrast and fog are contradictory. Any scale of contrast must deteriorate in the presence of fog because fog is an extra layer of density superimposed on proper density. Fog is objectionable because it adds this supplemental density and thereby interferes with the visibility of detail structures in the image on the radiograph, and makes it difficult if not impossible to differentiate between tissues of different opacities. Fog does not destroy detail in a radiograph any more than atmospheric fog destroys a landscape on a foggy morning. Perhaps, the trees, bushes and contour of the earth cannot be seen because of the fog, but if they were ever there, they are still there, and when the fog lifts the landscape is readily visible. The same thing holds true in radiography. Prevent fog from affecting a film, reduce fog to an acceptable amount and proper density, contrast and visibility are restored. It is not possible to prevent all fog from reaching the film, but the amount of fog must be reduced to a level where it does not interfere with visibility of detail.

There are potentially many kinds of fog which may affect a film and influence the scale of contrast in the radiograph. Age fog, chemical fog, heat, light, safelight and other types of fog are not of recent discovery and methods of preventing their formation and effect are known. Secondary radiation fog is, however, something to contend with in every x-ray exposure, and to the extent that is affects a film, the contrast scale is influenced and changed. Constant attention must be devoted to reducing the amount of secondary radiation fog and preventing it from affecting the film.

Secondary radiation fog is caused by: (1) the amount of primary radiation used. Primary radiation is produced by kilovoltage and milliampere-seconds. Either or both of these factors used to excess causes an imbalance and results in the production of unacceptable fog.

(2) The second cause for secondary radiation fog is tissue. Technicians cannot choose patients or the type of tissue to be x-rayed. But the technician can be aware that certain types of

tissue and certain circumstances result in an increase in the amount of fog. When these circumstances are present, the technician must be prepared to do something extra to minimize the effect of secondary radiation fog. Fluid is the fog producing medium in tissue, and soft tissue with a high content of fluid is most productive of secondary radiation fog. Osseous tissue, being quite solid with a lesser fluid content, is the least productive of secondary radiation fog. Too, when a volume of tissue is small and close to the film, as in radiography of the small extremities, no great amount of secondary radiation is produced and there is little opportunity for it to register an effect on the film. However, in an area, such as the lateral lumbar spine, all the conditions for production of excessive secondary radiation are present — a great volume and type of tissue, a large quantity of primary radiation, and the fact that the area of interest, the spine, is six to eight inches from the film, gives secondary radiation fog a chance to undercut the image of the spine and fog the film.

Since the formation of secondary radiation fog cannot be prevented, what can be done to minimize the influence of this fog on the radiograph? When an unacceptable amount of secondary radiation fog is evident there is an imbalance existing between the factors that produced the primary radiation. DO NOT REDUCE KILOVOLTS. REDUCE MILLIAMPERE-SECONDS. Excessive secondary radiation means there has been excessive primary radiation, and since mas. is the controlling factor in producing a quantity of radiation, change mas. If kilovolts are reduced in an attempt to reduce fog, it may well be that before fog is reduced to an acceptable level the kilovoltage will be so low that inadequate penetration results. Again, one problem would be solved, but only at the expense of introducing another.

If fog cannot be reduced to an acceptable level by realigning the factors used in the production of primary radiation, it becomes necessary to make use of one of the auxiliary accessories available for this purpose. Such auxiliary means are the grid, cone and filter.

The GRID is still the most effective device for reducing secondary radiation fog. It will be recalled that the efficiency of a grid depends on the total amount of lead and this is a function of grid ratio plus the number of lead lines per inch.

The CONE will aid in reducing an unacceptable amount of secondary radiation fog. However, even an inefficient grid will be more effective than the best cone for cleanup of secondary radiation. In combination, the grid and the cone, are the most effective, because the cone prevents the formation of some secondary radiation by confining the beam of primary radiation to a smaller area of tissue, while the grid traps secondary radiation after it has been produced and prevents it from fogging the film.

Finally, FILTRATION is an aid in preventing the formation of some secondary radiation by absorbing a portion of the longer wavelengths present in every beam of x-radiation. These have only sufficient penetrating power to go a certain depth in tissue and there set up secondary radiation which may strike a film and cause fog.

Density and Contrast are photographic properties of the radiograph, and the factors described, control and influence the production and maintenance of proper density and contrast. The concept of proper density and contrast must be established on an average amount of normal tissue in any body part, and with the use of a given selection of auxiliary accessories. From then on, changes from the average or from the normal in tissue or changes in the choice of accessories should be accommodated by a change in milliampere-seconds to avoid a change in proper density and contrast. Compensation through changes in kilovoltage is a hit-or-miss method. Assuming that a fortunate choice of kilovolts is made to compensate for some change in a set of conditions and density is not disturbed, the fog level may no longer be acceptable and structural detail may be obscured.

Kilovoltage values necessary for the penetration of various parts of the body are known; these will apply at all times. The values are:

BODY PART	KILOVOLTS
Small Extremities	60 kvp
Large Extremities (Knee, Shoulder, Femur)	80 kvp
Skull	85 kvp
Sinuses	70 kvp
Pelvis and A.P. Spine	70 kvp
Lateral Spines	85 kvp
Abdomen	70 kvp
G.I. Tract	90 kvp
Chest P.A.	80 kvp
Chest Lateral	90 kvp
Chest Oblique	85 kvp

These kilovoltage values might be termed necessary for penetration when a reasonable quantity of x-radiation is used to produce proper density. If these necessary kilovoltage levels are exceeded, some good is still achieved in the form of reduced exposure to the patient and fewer heat units per exposure to the x-ray tube. However, the value of these two advantages must be weighed against an overall change in scale of contrast and the possible production of excessive fog. When that stage is reached, quality is no more acceptable than that which is produced with kilovoltage too low for penetration. The important thing is to not use less than these necessary kilovoltage values. Inadequate penetration will result and probably will be followed by an excessive exposure in an attempt to produce proper density. An excessive quantity of x-radiation will never compensate for a lack of penetration.

A most graphic illustration of the improper application of milliampere-seconds and kilovoltage to maintain proper density and contrast is seen in one of the common methods of technique used in radiography of the lateral lumbar spine. It is generally agreed that this body area is one of the more difficult to radiograph satisfactorily over the wide range of patient sizes encountered, and to maintain consistently diagnostic radiographs. Because of the wide variation in tissue volume in this body area, a small adult patient will measure as little as twenty-four centimeters whereas a large patient may measure as much as forty centimeters or more at the level of the fourth lumbar vertebra. The following technique is an example of the type practiced in many x-ray departments:

CM.	24	26	28	30	32	34	36	38	40	250 mas
KV	66	70	74	78	82	86	90	94	98	

If this technique is analyzed, it seems unreasonable that the same quantity of x-radiation — 250 mas — is used on twenty-four and forty centimeters of tissue with the expectation of producing the same proper density on both. Nor does it seem correct that sixty-six kilovolts is adequate to penetrate twenty-four centimeters of tissue but that it requires ninety-eight kilovolts to penetrate forty centimeters of the same type of tissue, the only difference being in the volume of tissue in the two spines. Different amounts of the same type of tissue more reasonably require different amounts of x-radiation rather than different kinds of radiation. It should be quite obvious that twenty-four centimeters of tissue and sixty-six kilovolts will not be too productive of secondary radiation, so it is to be expected that the radiograph of the smaller spine in this example will show a very short scale contrast. Ninety-eight kilovolts and forty centimeters of tissue are

much more productive of secondary radiation fog and a completely different contrast scale will be evident in that radiograph. Since there is a wide difference in the volume of tissue in body parts, the maintenance of proper density and contrast is made more difficult by using a method of technique that introduces variations in film quality.

REVIEW QUESTIONS

1. Outline radiographic film quality.
2. What is a diagnostic radiograph? Discuss your definition.
3. What is radiographic density? What is proper density? How much change in density is required to make the change visible on a film?
4. How does kilovoltage influence density?
5. If you use kilovoltage to accommodate requirements for more density in radiography, how do you proceed when the maximum rating of a transformer is reached and density still is not proper.
6. What is radiographic contrast? How much is proper?
7. How is short scale contrast produced? This scale of contrast can often be associated with what other problem in radiography?
8. What causes secondary radiation fog?
9. What is the primary purpose of kilovoltage in radiography?
10. Discuss a concept of the minimum and maximum useful kilovoltages in radiography. Is there any good result obtained when more than maximum useful kilovoltage is employed?
11. Do you believe there is such a thing as "over-penetration" in radiography? If so, how is this visible on a radiograph?
12. Is there such a thing as "over-exposure" in radiography? How is this visible on a radiograph and how do you correct such a problem?

ANSWERS

ANSWERS

GEOMETRIC PROPERTIES OF RADIOGRAPH

The term, "DETAIL", in radiography is confused by the fact that the quality of detail is one which crosses the line between photographic and geometric properties of a radiograph. Image detail is influenced by both, and for the sake of clarity, it is well to define detail from two viewpoints and to differentiate between the factors that influence detail on the radiograph.

RADIOGRAPHIC DETAIL

As a photographic property, detail is defined as the presence and visibility of an image of some object on a film — the actual deposits of metallic silver that go to make up the image. In other words, if there has been enough of the right kind of x-radiation transmitted through an object, then an image of the object is cast on the film. If the image is not fogged by secondary radiation, or some other type of fog, the image is visible. Actually, detail is closely associated with proper density and proper contrast. If these two qualities are present, there has to be maximum detail. Something may happen to make the image unsharp and to make the structural detail indefinite, as cast on the film. This has nothing to do with the presence and visibility of the image.

Somewhat analogously, the image you see in the mirror is you, the curve of the nose, color of the eyes, lip contour, the chin, droop of the shoulders, these are details of your image and as long as they are faithfully recorded in the reflecting surface of the mirror, the image is complete and can be seen. You may move, or the mirror may be imperfect so the image is not sharp and is distorted, but the image is still there and can be seen.

Detail indicates the presence and visibility of an image on the film with no reference to its sharpness or accuracy. Detail is dependent on proper density and contrast. How much detail is necessary in radiography? A maximum amount, for only that amount will show a complete image, and without it the real purpose of the radiographic examination is defeated.

The term, DEFINITION, more properly relates to sharpness, definiteness of detail. Even though there is a complete image on the film and it is visible, the sharpness of structural details may be indefinite. That sharpness, that accuracy are geometric properties of the radiograph.

X-ray is a form of electromagnetic radiation and as such it follows many of the same rules that govern light and the casting of shadows by light. There is one big difference in that light does not cast an image but rather an outline or silhouette of an object. If you place your hand between a source of light and this page, your hand breaks the beam of light and an outline of your hand is cast on the page. If your hand is placed between a source of x-radiation and an x-ray film, your hand does not break the beam of x-radiation. It may interfere with the passage and absorb some of that x-radiation, but a percentage of the beam passes through the hand and casts an image rather than a silhouette of the hand on a film.

SHARPNESS OF DETAIL

A second aspect from which detail may be studied is its sharpness — DEFINITION. How much definition is necessary in radiography? It is most unlikely that maximum sharpness of detail can be produced in radiography because of limitations imposed by the patient and the method of recording the image. Add to these the limitations of what the unaided human eye can see, and it becomes evident that the objective should be to produce as sharp an image as circumstances permit and require. The eye can detect unsharpness in radiography of osseous tissue when the unsharpness exceeds a line one-tenth millimeter wide; the limitation is placed at a line two-tenths millimeter wide in radiography of soft tissue.

Loss of definition may be the result of:

1. MOTION UNSHARPNESS (UM) — which may be voluntary or involuntary on the part of a patient.

2. GEOMETRIC UNSHARPNESS (UG) — which is influenced by focal-spot size, object-film distance and target-film distance.

3. MATERIAL UNSHARPNESS (MU) — which is influenced by film, intensifying screens and film-screen contact.

Geometric and material unsharpness are present in a radiograph in a known amount which does not vary as long as the factors affecting them remain unchanged. If the loss of definition resulting from these factors is unacceptable, a definite change must be made in one or more of the factors that influence geometric and material unsharpness. Motion unsharpness, on the other hand, is a variable thing and is governed by the circumstances of the moment. It is often difficult to attribute evidence of poor definition on a radiograph to any one cause of unsharpness. Likewise, correcting one factor that contributes to unsharpness may cause another to become more effective, so that in the end, the radiograph may not exhibit the improvement expected.

Motion Unsharpness (UM)

Motion is, perhaps, the more obvious cause for a loss of definition in radiography. Motion may be voluntary or involuntary. As the term indicates, voluntary motion connotes an unwillingness on the part of a patient to stop motion during an exposure. This type of motion must be eliminated, usually by means of restraining bands, head clamps or any of the several immobilizing devices available for the purpose. These devices serve a most useful purpose in all radiographic procedures and when it is realized that a patient has to move as little as one-quarter millimeter to have the effect of such movement become evident on a radiograph, there is ample justification for taking the few seconds necessary to apply one of the immobilizing devices. Voluntary motion must be eliminated but never through the medium of any member of the x-ray department staff holding the patient.

Involuntary motion, to a large extent, is associated with physiologic action of body organs, but may also be associated with whole classes of patients, such as infants or unconscious patients. The effect of involuntary motion arising from the physiologic action of body organs varies in individuals and in a particular organ system. This type of motion is not stopped, but the effect of this motion can usually be arrested by means of a short exposure time. How rapid the exposure time must be is governed by the rate and amplitude of movement in an organ. For example, motion of the heart and great vessels is approximately five millimeters-per-second, so in radiography of this body area a very rapid exposure time is justified when diagnostic interest centers on those organs or on tissue likely to be affected by motion of those organs. On the other hand, motion associated with the genito-urinary tract and parts of the gastro-intestinal tract is a relatively slow, rhythmic type of motion, and extremely short exposure times are not necessary to arrest the effect of motion in these areas.

Geometric Unsharpness (UG)

This type of unsharpness is influenced by size of the x-ray tube focal spot, object-film and target-film distance. Geometric unsharpness may be expressed in the formula:

$$UG = \frac{\text{Focal-spot Size} \times \text{Object-film Distance}}{\text{Target-object Distance}}$$

FOCAL SPOT SIZE — has no influence on detail as such but rather on definition or sharpness of detail. It is a fallacy to say that a one millimeter focal spot produces any more detail than a four millimeter focal spot, all other conditions being the same. That the one millimeter focal spot produces greater sharpness of detail than the four millimeter focal spot is proven by the previous formula. Any improvement in sharpness of detail resulting from use of a smaller focal spot becomes less significant as object-film distance is minimized, e.g., in radiography of the hand, using direct exposure, there is no difference in visible sharpness of detail produced with a large or small focal spot. Too, the effect of a larger focal spot is minimized to some degree by the use of a greater

target-film distance, e.g., in radiography of the lateral cervical spine, at six foot target-film distance, there is no visible difference in sharpness of detail produced with a large or small focal spot.

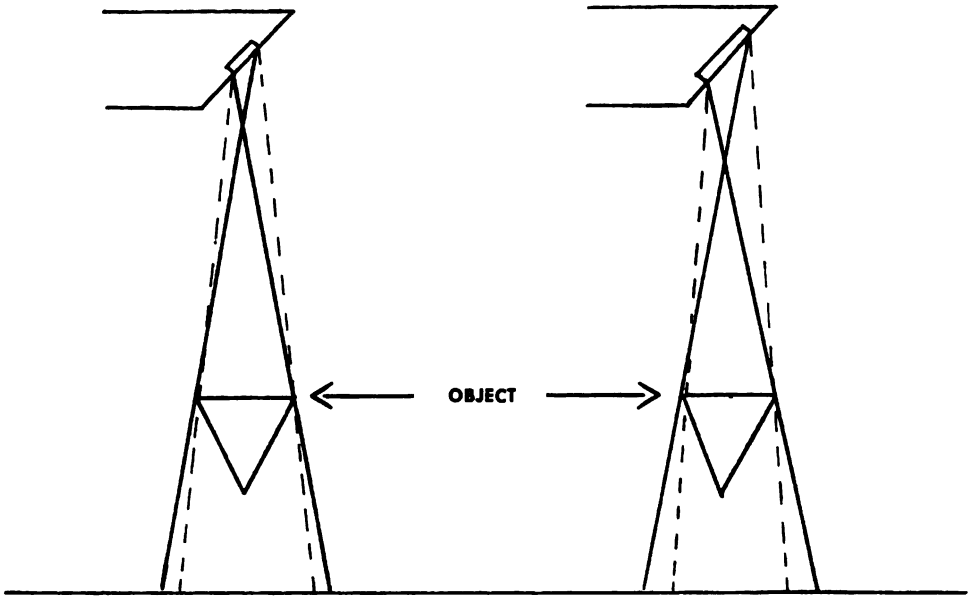


FIGURE 57. — FOCAL SPOT SIZE AND DETAIL SHARPNESS

The effect of focal spot size on geometric unsharpness is shown in this example:

PART — **Lateral Lumbar Spine**

Focal-Spot Size — 1 mm
Object-Film Distance — 8 inches
Target-Object Distance — 32 inches
Then:

$$\frac{1 \times 8}{32} = \frac{8}{32} = .25 \text{ mm unsharpness}$$

Focal-Spot Size — 2 mm
Object-Film Distance — 8 inches
Target-Object Distance — 32 inches
Then:

$$\frac{2 \times 8}{32} = \frac{16}{32} = .5 \text{ mm unsharpness}$$

In both instances, the unsharpness exceeds the limitation of what the unaided eye considers sharp but by a small amount in one instance and by more than five times in the other instance.

When a combination of two or more causes, each responsible for some unsharpness, are united in a radiographic procedure, and the combined unsharpness exceeds what the eye considers to be sharp, some effort has to be made to reduce the unsharpness. For example, in radiography of the lateral lumbar spine, the object-film distance is great (6-8 inches), intensifying screens are used, target-object distance may be relatively short. Each of those conditions is responsible for some unsharpness, and if the unsharpness caused by a large focal spot is added to these, there is hardly any doubt that unsharpness will be visible. Therefore, it is good technique to use the small focal spot in radiography of this area. However, no thinking technician will hesitate to change to a larger size focal spot if exposure factors are such that damage to a small focal spot would result.

OBJECT-FILM DISTANCE — It has been indicated previously that, since x-radiation may be compared to visible light, it follows many of the rules governing formation of shadows by light. One of these rules is concerned with the sharpness of detail resulting from object-film distance. The hand, used previously to illustrate the casting of an outline by light, may be used to illustrate sharpness of that outline, resulting from object-film distance. With the light source at some dis-

tance, and the hand on this page, the edges of the silhouette are sharp and clearly defined; move the hand farther away from the page and edges of the silhouette become visibly indistinct. If put in the form of a rule, the influence of object-film distance on detail sharpness would be: ALWAYS PLACE THE OBJECT AS CLOSE TO THE FILM AS POSSIBLE TO MINIMIZE LOSS OF DETAIL SHARPNESS.

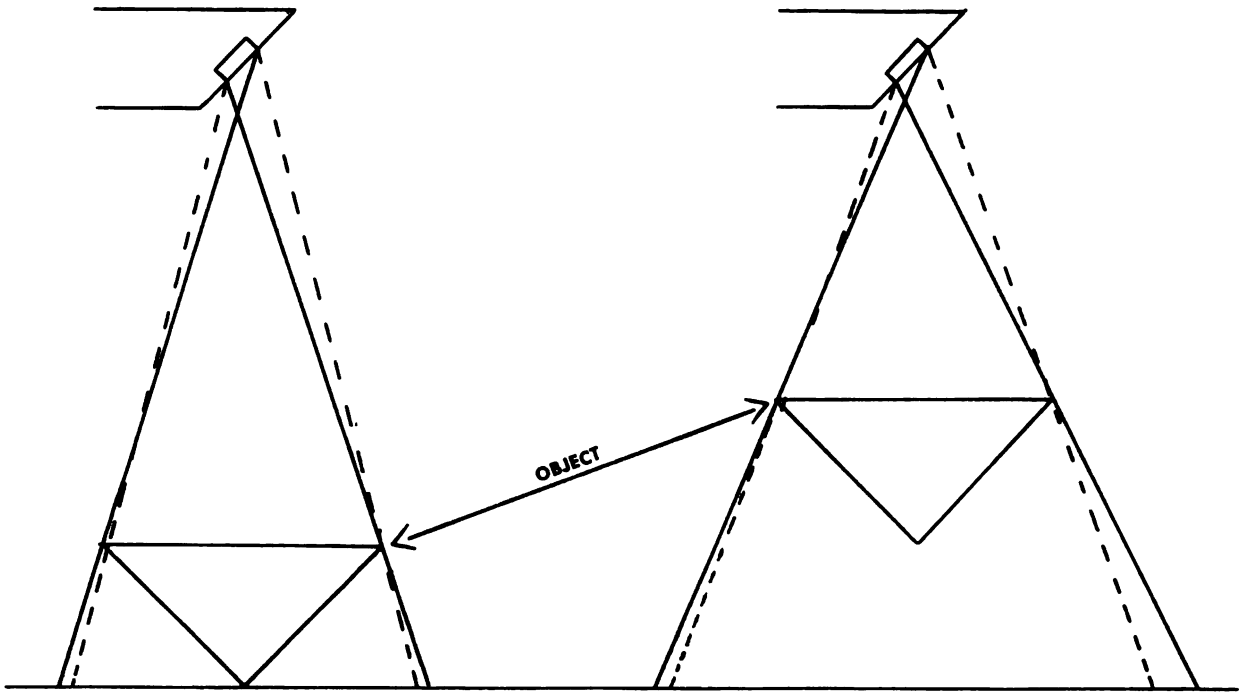


FIGURE 58. — OBJECT - FILM DISTANCE AND DETAIL SHARPNESS

TARGET-FILM DISTANCE — Loss of definition in radiography is likewise a function of target-film distance. Sharpest definition is evident when the effective focal spot is used at a reasonable target-film distance. Longest target-film distance is not indicated because an increase to more than reasonable distance may result in the introduction of factors, such as longer time of exposure, with attendant possibility of motion to cause unsharpness, and off set the gain from the long distance. Within the limitations of equipment — capacity of generator and x-ray tube, radius of the grid, tube carrier design — target-film distance should be established at a reasonable point to minimize loss of detail sharpness.

Material Unsharpness (UM)

Material unsharpness is a function of the film, the type of intensifying screens used in a procedure and closeness of contact between screens and film.

FILMS — all films used in medical radiography, whether screen or direct exposure type, are, of themselves, capable of producing greater detail sharpness than the unaided eye can detect. The resolving power of x-ray film is approximately twenty lines per millimeter. In extremity radiography, there is nothing to choose between the two types of films insofar as sharpness of detail is concerned.

INTENSIFYING SCREENS — It has been indicated that intensifying screens are the largest single contributing factor to a loss of detail sharpness with the exception of motion. Unsharpness

is a result of size of crystals and emulsion thickness. The unsharpness factor of various speed screens can be accepted as approximately:

0.20 mm for the slow screens.
0.25 mm for the medium speed screens.
0.35 mm for fast screens.

Obviously, then, all other factors being equal and within limits for the acceptability of unsharpness, intensifying screens cause a noticeable lack of definition. Nevertheless, the speed of these screens makes them a necessary item in radiography of heavier body parts as well as other body parts where short time exposures are essential.

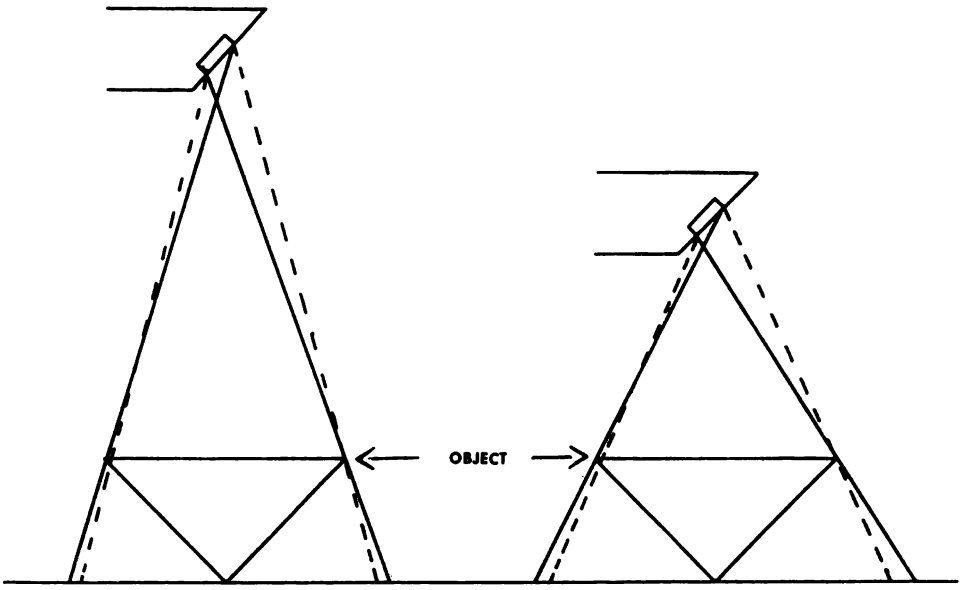


FIGURE 59. — TARGET - FILM DISTANCE AND DETAIL SHARPNESS

SCREEN-FILM CONTACT — Actually screen-film contact is more a function of cassettes than of the screens as such. Regardless of the source of poor contact between the screens and film, the result is a noticeable loss of sharpness.

Total Radiographic Unsharpness

Total radiographic unsharpness is approximately the sum of geometric unsharpness (ug) plus motion unsharpness (um) if this sum is greater than the blurring effect of the film or screen (material unsharpness). Where the blurring effect of the film or screen is greater than ug plus um, the total unsharpness will be this blurring effect.

We are now in a position to calculate total unsharpness for any given set of radiographic conditions. In the examples shown below the formula has been applied to several typical cases.

P.A. hand, direct exposure (cardboard holder). 40 mas, 60 kvp.
Target-film distance 40″; object-film distance 1″.
Material unsharpness of film, conservative estimate, 0.025 mm.

Rot. Anode	Ma	Time	Ug	Um	Mu	Total Unsharpness
2 mm.	200	0.2	.051	0	0.025 (disregard)	0.051
1 mm.	100	0.4	.025	0	0.025 (disregard)	0.025

In the example where the 2 mm. focal spot is used, material unsharpness may be disregarded since it is less than ug. With the 1 mm. focal spot, material unsharpness is equal to ug so it may again be disregarded.

As total unsharpness in both examples is less than .1 mm., the eye would consider all radiographs to be equally sharp.

P. A. Chest, 10 mas, 80 kvp.
Target-film distance 72"; object-film distance 6".
Motion of heart, lung tissues, great vessels 5 mm. per second.

Rot. Anode	Ma	Time	Ug	Um	Mu	Total Unsharpness
2 mm.	400	1/40	.18	0.12	0.05 (disregard)	0.30
1 mm.	200	1/20	.09	0.25	0.05 (disregard)	0.34

Lat. Lumbar Spine, 200 mas, 85 kvp.
Target-film distance 40"; object-film distance 8".

Rot. Anode	Ma	Time	Ug	Um	Mu	Total Unsharpness
2 mm.	200	1.0	0.5	0	0.05 (disregard)	0.5
1 mm.	100	2.0	0.25	0	0.05 (disregard)	0.25

To all of the total unsharpness figures should be added possible voluntary patient motion. Remember, if a patient moves only ¼ mm. because of an uncomfortable position during exposure, the resulting film will exhibit unsharpness.

RADIOGRAPHIC DISTORTION

True distortion and magnification are two forms of inaccuracy in the image of a patient as projected on the radiograph. Magnification causes an increase in the size of the image. Within limits, magnification is not objectionable, but when magnification reaches the point where unsharpness of detail becomes objectionable, magnification is no longer acceptable. Magnification in radiography is influenced by target-film distance and object-film distance.

Target-Film Distance

Since magnification and detail sharpness cannot be completely separated when considering radiographic film quality, some of the same factors which influence one quality must also be considered for the effect they have on the other. Object-film distance will always be a variable because patients differ in size, but the detrimental effect of great object-film distance, normal as it may be, will be minimized by the use of a reasonable target-film distance.

Object-Film Distance

The remarks about object-film distance and its influence on detail sharpness likewise apply to the influence of object-film distance on magnification of a patient's image in radiography. If stated in the form of a rule, then, "USE THE SHORTEST OBJECT-FILM DISTANCE AND A REASONABLE TARGET-FILM DISTANCE TO MINIMIZE MAGNIFICATION".

Magnification, as discussed here, is not to be confused with an intentional controlled radiographic magnification. A well-known rule of optics states — the shadow of any object placed equidistant between the light source and a film will be enlarged twofold. This is sometimes done for the purpose of making the visibility of an object or tissue condition more evident. In this instance, object-film distance is increased to secure magnification; and the loss of detail sharpness is minimized by use of a very small focal spot, .3 mm, x-ray tube. If object-film distance

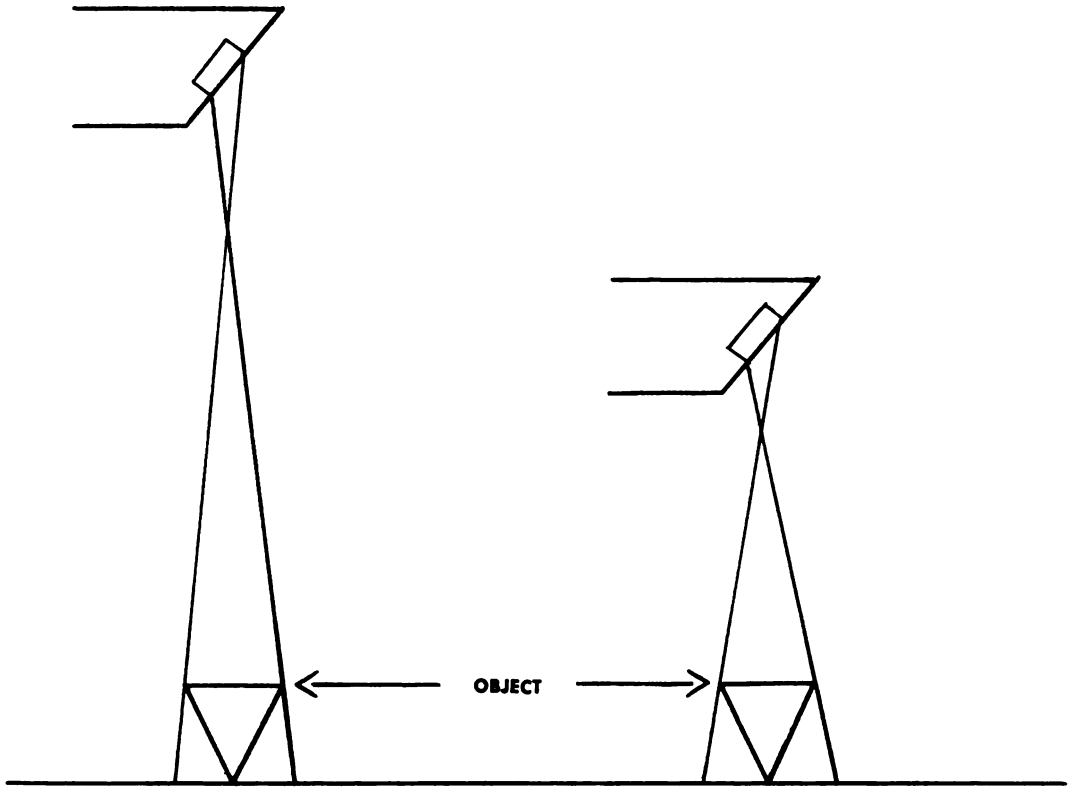


FIGURE 60. — TARGET - FILM DISTANCE AND MAGNIFIED DISTORTION

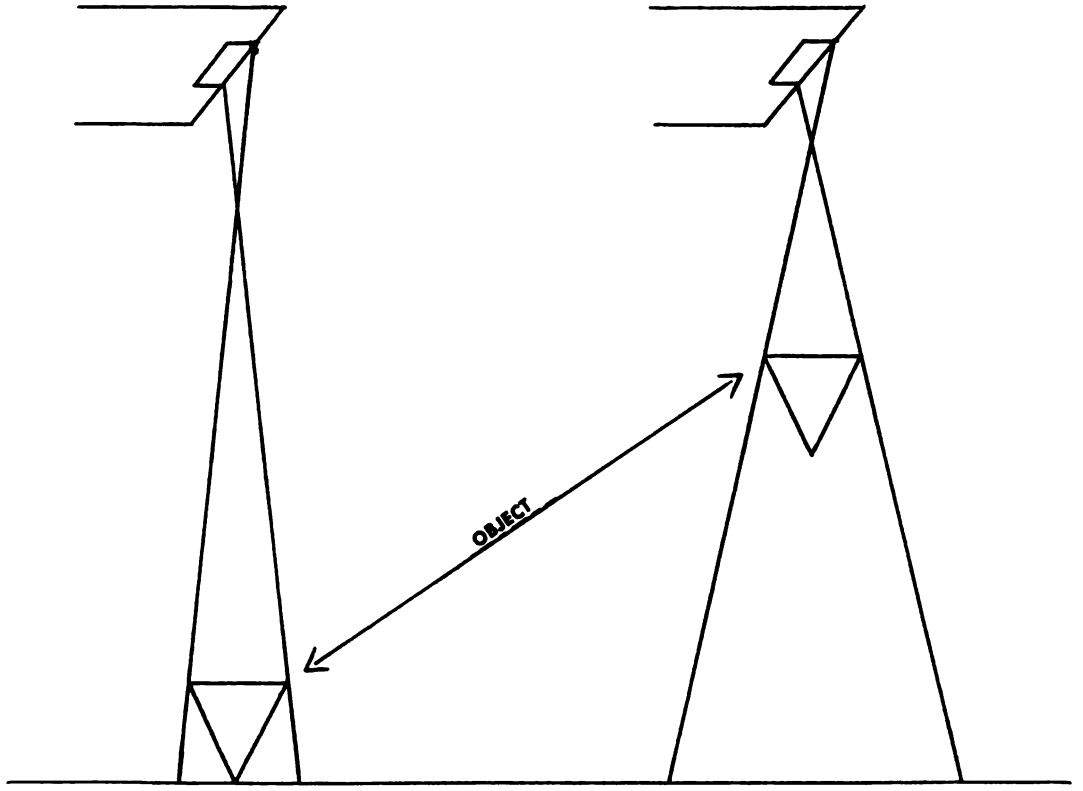


FIGURE 61. — OBJECT - FILM DISTANCE AND MAGNIFIED DISTORTION

and target-object distance are the same, a two-times magnification results in the image of the patient as shown on a radiograph. If the patient is twice as far from the film as the x-ray tube target is from the patient, a four time magnification of image size on the film results.

True Distortion

As distinguished from magnified distortion, true distortion results in an elongation or foreshortening of the image of a body part. True distortion may also cause a displacement in the normal relations of one body part to surrounding parts. Because of configuration of body parts and the methods of projecting an image of a multi-and-varied-plane object on a single plane film, it is not possible to completely eliminate true distortion of all parts in a body area during radiography. However, there is one plane of greatest diagnostic interest in the patient at any time and that plane should be shown with a minimum of true distortion. This is the reason for making several radiographic exposures of a body part and a reason for supplementing survey films of a large body area with small films localized to a particular area. No radiographic examination is necessarily complete with one film and one exposure.

For the purpose of eliminating super-imposition of the image of one body part over the area of interest on a radiograph it is sometimes necessary to direct the principal ray at some angle other than a right angle to the plane of the film. In these instances, elongation or foreshortening in all except the area of interest results, but the rule to minimize inaccuracy in the projected image of a body part should be, "PLACE THE PLANE OF INTEREST AND THE PLANE OF THE FILM PARALLEL TO EACH OTHER AND AT A RIGHT ANGLE TO THE DIRECTION OF THE CENTRAL RAY".

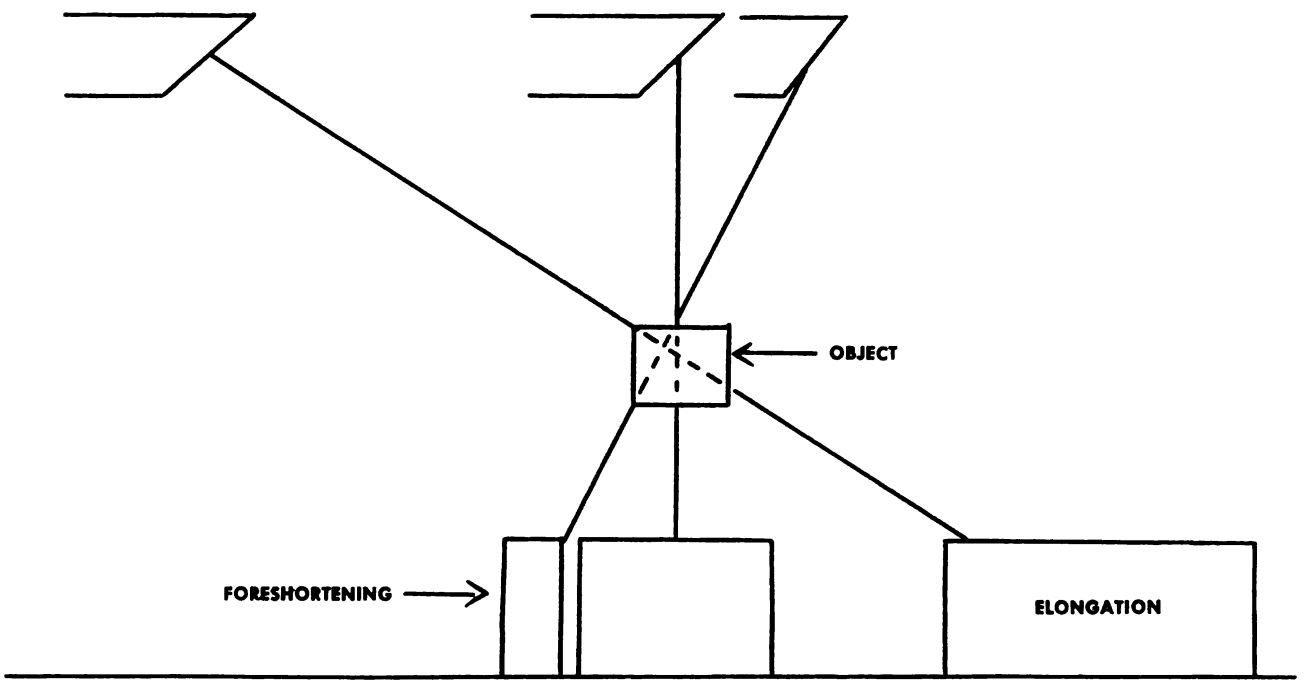


FIGURE 62. — TARGET - OBJECT - FILM ALIGNMENT AND TRUE DISTORTION

FILM QUALITY CHART

It is good technical practice to establish a method of procedure which will incorporate as many firmly founded factors as possible and to follow that procedure as often as possible for the sake of reproducing high quality radiographs. However, occasions continue to arise when it is necessary or advisable to change from routine practice. If the technician is aware of what effect the change will have on film quality, compensation can usually be made in exposure factors so that the change in routine will not be reflected in the production of an unacceptable radiograph. The following chart lists some of the changes in routine that may be introduced into a technical procedure, resulting in a change in film quality. The best way to appreciate the chart is to expose the model radiograph and then expose another radiograph with one or other change as indicated on the chart. See for yourself what happens to film quality.

A satisfactory radiograph of a hip is made with these conditions:

70 kv, 75 mas, 40″ T.F.D., 8:1 ratio, 60 line bucky, 3 mm. Al. filter, regular film, medium speed screens, proper cone. Without compensating in technique, the changes listed at right are made — one at a time. Is density increased or decreased; contrast — longer or shorter scale; detail — more or less; definition — more or less sharp; distortion — greater or less?

	DENSITY	CONTRAST	DETAIL	DEFINITION	DISTORTION
Increase T.F.D. 10%					
Increase T.F.D. 25%					
Increase object-film dist. 3 in.					
Increase object-film dist. 7 in.					
Increase kilovoltage 3%					
Increase kilovoltage 20%					
Decrease ma 50%					
Decrease kv 10%					
Increase mas 20%					
Increase mas 50%					
Use 8:1, 80 line bucky					
Use 12:1, 80 line bucky					
Use 16:1, 60 line bucky					
Use stationary grid, 5:1, 80 line					
Use stationary grid, 10:1, 100 line					
Use regular film in C.B.H.					
Use non-screen film in C.B.H.					
Use non-screen film in cassette					
Use high-speed film					
Use high-speed screen					
Load cassette with two films					
Use lead-back cassette in place of non-lead back					
Overdevelop 50%					
Double mas and halve developing time					
Center tube 3" lateral to part					
Center tube 12" superior to part & angle back to center					
Use cassette with cold screens					
Use extension cylinder (fully extended)					
Use extension cylinder (collapsed)					
Add 2 mm. Al. filter					
Use no cone					

FIGURE 63.

Note: It is not difficult to compensate for a change in film quality, resulting from some alteration in procedure, if the effect of such an alteration is anticipated. After studying the theory of film quality, produce a radiograph of some phantom, similar to the model described above, and then make the variations listed. Study the effect on film quality and determine what compensation would be necessary to maintain the original quality.

REVIEW QUESTIONS

1. Discuss radiographic detail, detail sharpness and visibility of detail.
2. What are the principal causes of unsharpness in radiography?
3. Can maximum radiographic detail be produced with less than maximum definition in the same radiograph?
4. What are the two most prominent causes for loss of detail sharpness?
5. Which is the most important of all qualities in a radiograph?
6. In radiography of the lateral view of the femoral neck, elongation of the object image is often produced. Does this more likely result because of mal-centering of x-ray tube or mal-placement of the cassette in relation to the plane of the object?
7. Why is 72" T.F.D. recommended in radiography of the lateral cervical spine?

ANSWERS

ANSWERS

Chapter 9

A METHOD OF RADIOGRAPHIC PROCEDURE

RADIOGRAPHIC CALIBRATION

Before x-ray exposure factors can be correctly established on any generator, with reasonable assurance that x-ray film density can be duplicated with a variety of control settings, the unit must be radiographically calibrated. Until this is done, a technician has no assurance of any flexibility in the selection of exposure factors. Unless the generator is radiographically calibrated, the technician is practically restricted to the use of a given milliamperage and time of exposure at a specific kilovoltage, and effectively, the patient has to be fitted to the x-ray unit rather than be accommodated by the machine.

Radiographic calibration means that film density will be the same as long as the same kilovoltage and milliampere-seconds are used, regardless of the combination of milliamperes and time used to obtain the total. For instance, a set of technical factors may call for the use of 80 kvp and 50 mas. Under normal conditions, this may be done with 50 ma × 1 second. But because of changed conditions, it may be necessary to shorten the time of exposure to overcome a problem of patient motion. The technician must know that any of these combinations, 100 ma × 1/2 second, 150 ma × 1/3 second, 200 ma × 1/4 second, 300 ma × 1/6 second, 400 ma × 1/8 second, 500 ma × 1/10 second will produce the identical exposure, and he must be confident that film density will remain unchanged from the original, regardless of which new combination is selected. Without this assurance and without equipment that will perform in this manner, it is impossible to practice a milliampere-second technique over the full range of the x-ray generator.

Complete radiographic calibration of an x-ray generator requires meticulous attention to details, and involves some knowledge of the x-ray control panel. Too, special accessories, such as a spinning top and an aluminum penetrometer are required for such a procedure. However, a technician can do a quick check on the ability of a generator to duplicate density over its working range.

Take four chest radiographs at 80 kvp, 50 ma × 1/5 second, 100 ma × 1/10 second, 200 ma × 1/20 second and 300 ma × 1/30 second. Use the same patient, same cassette and screens, process the films together. In other words, all steps in the procedure must be the same except the relationship of milliamperes and time of exposure, but the sum of each combination must be the same. Be sure the patient inhales the same amount of air for each radiograph. When the films are dry, compare them for density. If the first three films match, but the one exposed at 300 ma shows less density, it is quite evident the machine is not producing the same quality and quantity of x-radiation over its entire range. The cause is a problem for the manufacturer's representative to determine, and it is his responsibility to see that the fault is corrected. If corrections cannot be made so that the density of the four films match, it seems evident that the x-ray generator should be rated at 200 ma rather than 300 ma.

Radiographic calibration is important to the accurate practice of x-ray technique. Film density is what the radiologist interprets and the x-ray generator must be capable of producing a specific density repeatedly as long as the technician sets the controls at indicated points to produce the same quality and quantity of x-radiation.

BUILDING THE TECHNIQUE CHART

At some time in every technician's career, there arises a need or an occasion to build a technique chart. Equipment manufacturers usually supply a technique chart, but upon application at an installation, it is often found that the exposure factors on such charts do not produce diagnostic radiographs. Manufacturers make an honest effort to deliver a usable set of exposure factors for a newly installed x-ray unit. Due to many variables it is a pure coincidence if the suggested factors produce a diagnostic radiograph at a conventional installation. At best, any technique chart should be accepted as a suggestion or close approximation of exposure factors expected to produce an acceptable radiograph. A technician has no right to expect technical factors, developed under a given set of conditions, to work unless those conditions are duplicated.

There are several methods of establishing and practicing x-ray technique. Each of these methods evolves into a chart of exposure factors to be used in radiography of various body parts. One thing is common to all methods of x-ray technique — exposure factors must be based on an average amount of normal tissue in any body part. Only from that solid base can compensation be made to take care of variations from an average amount or for other than normal tissue.

Methods of Establishing Exposure Factors

Three acceptable methods of technique are: (1) Phototiming; (2) The use of Fixed Kilovoltage and Variable Milliampere-seconds; (3) The use of Variable Kilovoltage and Fixed Milliampere-seconds. Regardless of the method to be developed, there are certain decisions to be made before any exposure factors are developed:

1. The brand and speed of intensifying screens.
2. The brand of film.
3. Extremity radiography to be done with screens and/or direct exposure.
4. Target-film distance.
5. Ratio and radius of grid.
6. Moving bucky grid or stationary grid.
7. Automatic or manual processing of films.

After decisions are made regarding the seven variables listed above, a method of technique can be established. Any time one of the seven fixed items is changed from the original, a factor to compensate for the change must be known and introduced; else the quality of films will change.

The first method, Phototiming, does not eliminate the need for making these decisions, even though exposure time will be automated, because such things as speed of intensifying screens and film, will enter into the establishment of photo-tube voltage by the service engineer. When phototiming is used, the choice of exposure factors will revolve around, (1) the use of kilovoltage adequate for penetration; (2) the selection of milliampere values sufficiently high to permit exposure times within the limits of the safety timer and with consideration for the minimum accurate time permitted by the phototimer; (3) choice and use of the proper scanner which is dependent on the size of area to be radiographed. If the universal type scanner is used, there is no choice in this respect.

The other two methods of practicing x-ray technique will require the logical selection of kilovoltage, milliamperage and time of exposure, based again on radiography of the average normal. Since either method is capable of producing a diagnostic radiograph, and since there is nothing to choose between the two methods insofar as proper geometric quality of the radiograph is concerned, the choice will be made because one or other method is more capable of producing and maintaining proper photographic quality in the radiograph.

Then:

1. Which method is more simple in application?
2. Which method is likely most often to result in the production of the diagnostic radiograph?

A COMPARATIVE ANALYSIS OF FIXED vs VARIABLE KILOVOLTAGE METHODS OF TECHNIQUE

A comparative analysis of the two methods indicates these salient features:

FIXED KILOVOLTAGE	VARIABLE KILOVOLTAGE
DENSITY	
1. Measurement of tissue volume is essential.	1. Measurement of tissue volume is essential.
There is an average size in any body part, this average size is composed of a proportion of soft tissue to osseous in the average normal. This proportion remains pretty much the same in an above average or below average size normal. Average size is determined by measuring a great number of body parts and includes a range of three to four centimeters of tissue thickness. It is not given a specific centimeter thickness.	
2. Penetration of tissue is based on the fact that radiation of a certain wavelength will adequately penetrate an average amount of normal tissue and produce proper radiographic density with a reasonable exposure. Variation from the average in tissue volume or the normal in tissue condition is accommodated by an increase or decrease in quantity of radiation, not a different wavelength or kind of radiation.	2. Milliampere-seconds is selected at random and the kilovoltage to produce proper density is determined using that mas. Variation from the average in tissue volume or the normal in tissue condition used in establishing a starting kilovoltage is accommodated by adding or subtracting some value of kvp, thereby changing wavelength of the radiation. Size of part is very important because size becomes the basis for changing penetration, and quantity of radiation remains the same from smallest to largest part in body area.
3. Measurement of tissue volume is not critical because a variation of one or two centimeters in size is not immediately reflected in a change of exposure factors. Kilovoltage which supplies penetration is always adequate for any volume of tissue in the same body area. Changes in tissue volume call for changes in quantity not quality of radiation to maintain film density.	3. Measurement of tissue volume must be accurate because it is the basis for changing kvp (2 kvp per centimeter) which, in turn, is used as variable factor to change film density. It is not unreasonable to believe that the same technician will measure a body part differently at different times and it is even more likely that two different technicians will not measure tissue thickness the same. The kilovoltage used is barely sufficient for a given centimeter thickness of tissue.
4. Is based on higher than usual kvp values. Slight changes in density are not often necessary since use of higher kvp inherently introduces density differences in radiographic image which are unique to the patient, and alteration of technique is not necessary to produce these changes. Any change in density must amount to 30% as a minimum, and this can be made more accurately with mas than by changing kvp.	4. Is generally based on the use of lower kilovoltage for the majority of radiography. Lower kilovoltages are critical and kilovoltage has a variable effect on film density, dependent on kvp range. Slight changes in film density can be made by changing kvp, but changes may not be accurate because of variable effect of kvp.

5. Fixed kilovoltage is always within the maximum rating of a transformer. There is no reasonable limit to the number of milliampere-seconds that can be used because ma. and time are inversely proportional to each other and can be combined in a most advantageous way to secure a desired mas.	5. By adding kilovoltage as tissue volume increases variable voltage must eventually reach the maximum rating of a transformer beyond which there is no more kvp. available, so maximum patient size is limited by transformer rating.
CONTRAST	
1. Fixed kilovoltage is the quantity adequate for penetration without the production of an uncontrollable amount of secondary radiation fog. Fog varies only because of different volumes of tissue, not because of tissue and kilovoltage.	1. Variable kilovoltage extends over a considerable range of available kilovoltage from the lowest to the highest. There is a noticeable development of secondary radiation fog as kilovoltage is increased for heavier body parts.
2. Fixed kilovoltage makes use of higher kilovoltage and consequently produces a longer, more useful scale of contrast.	2. Variable kilovoltage is often based on a low kilovoltage range for the majority of radiography and consequently produces a short scale contrast resulting in excessive exposure and films that are of questionable diagnostic value.
3. When circumstances require a change in kvp-mas relation, this is done without disturbing acceptable radiographic quality.	3. When circumstances require a change in kvp-mas relation, any initial discrepancy in film quality is maintained or magnified.
GENERAL	
1. Use of fixed kilovoltage results in lower exposure dose to average and less-than-average size patients. Only the very largest patients, who are in a minority, receive larger exposure doses.	1. Use of variable kilovoltage will generally result in larger exposure dose to all patients except very large individuals. The vast majority of radiography is done on average and less-than-average size patients.
2. Fixed kilovoltage causes fewer heat units-per-exposure in the majority of instances.	2. The use of variable kilovoltage, particularly in the lower range of kilovoltage, produces more heat units-per-exposure.

SUGGESTED PROCEDURE FOR BUILDING A TECHNIQUE CHART

If a method of technique, employing fixed kilovoltage, is to be developed, proper exposure (mas) factors must be established for each body part, in the average size classification. The range of centimeter thicknesses to be encountered in all body parts can be grouped in three classes: less-than-average, average, greater-than-average; and in all body parts, except the chest and lateral lumbar spine, it will be found that the vast majority will be grouped in the "average" classification. Since the chest and lateral lumbar spine areas extend over a wide range of centimeter thickness it will be advantageous to establish for these areas at least five or six size groups, each embracing two or three centimeter thicknesses. In this way, more accurate control of film density can be maintained over the entire range of sizes.

When the seven choices, listed earlier, have been made, determine the milliampere-second value necessary to produce proper density in a radiograph of the selected part, and establish this as "average mas". Use half the average mas when a part in the same body area is less-than-average size, but normal; and double the average mas when parts in that body area are greater-than-average size, but normal. The milliampere-second value is established on the ideal body part, and when a change from the ideal takes place, an appropriate change in milliampere-seconds must be

made. For instance, the size of a part may be average, but because of a pathological condition or for some other reason, good judgment and experience indicates that the part should be classed as less-than or greater-than average, with exposure changed accordingly. The ability to make judgments of this type must be developed through experience.

Example:

Part	Position	CM	Classification	KVP	MAS	Screen	Film	Grid	Processing
Ankle	A.P.	7-10	Average	60	8.33	Yes	Reg.	No	68°—5 Min.
Ankle	A.P.	4-6	Less-than-Av.	60	4.17	Yes	Reg.	No	68°—5 Min.
Ankle	A.P.	11-13	Greater-than-Av.	60	16.7	Yes	Reg.	No	68°—5 Min.

Kilovoltage remains the same, whether screen or direct exposure is used. Kvp is based on the amount and type of tissue not a method of examination. When a set of exposure factors is established under a selected set of conditions, exposure factors remain fixed until the set of conditions change. Compensate for the new conditions by an appropriate change in mas.

The same procedure is followed for each body part to be radiographed, always basing the "average mas" on the average, normal part in every area. The following chart lists various body parts, average centimeter thickness and fixed kvp to be used in this method of technique. Mas values are not given on the chart nor is target-film distance because these are some of the variables that must be established on the scene taking into consideration the equipment in use.

PART	POSITION	AVG. CM. THICKNESS	KVP	PART	POSITION	AVG. CM. THICKNESS	KVP
HAND	P.A.	3-5	60	C. SPINE	A.P.	11-14	80
WRIST	P.A.	4-6	60	C. SPINE	OBL.	11-14	86
WRIST	LAT.	5-8	60	C. SPINE	LAT.	11-14	86
FOREARM	ALL	6-9	60	ATLAS-AXIS	A.P.	12-16	80
ELBOW	A.P.	6-9	60	L. S. JOINT	LAT.	35-38	86
ELBOW	LAT.	7-10	60	SKULL	LAT.	16-18	86
HUMERUS	ALL	7-10	60	SKULL	P.A.	18-21	86
SHOULDER	A.P.	13-16	80	SKULL	OCC.	18-21	86
CLAVICLE	A.P.	13-16	80	SKULL	SMV.	23-26	86
FOOT	A.P.	7-9	60	SINUSES	MAX.	18-22	80
FOOT	LAT.	7-9	60	SINUSES	FRON.	18-22	80
OS CALCIS	AXIAL	8-13	60	SINUSES	SPH.	21-24	80
ANKLE	A.P.	7-10	60	SINUSES	LAT.	11-14	80
ANKLE	LAT.	6-9	60	MASTOID	LAT.	14-17	66
LEG	A.P.	9-12	60	MANDIBLE	P.A.	12-15	86
LEG	LAT.	8-11	60	MANDIBLE	LAT.	10-13	66
KNEE	A.P.	11-14	80	NOSE	LAT.	——	60
KNEE	LAT.	10-13	80	ESOPHAGUS	P.A.	20-25	90
PATELLA	AXIAL	——	80	ESOPHAGUS	LAT.	28-32	90
FEMUR	A.P.	14-17	80	STOMACH	P.A.	18-22	100
FEMUR	LAT.	13-16	80	COLON	P.A.	18-22	100
PELVIS	A.P.	17-20	70	GALL BLADDER	P.A.	18-22	76
HIP	A.P.	17-21	80	ABDOMEN	A.P.	18-22	70
HIP	LAT.	20-24	80	CHEST	P.A.	23-25	80
L. SPINE	A.P.	17-21	70	CHEST	LAT.	28-33	90
L. SPINE	OBL.	18-22	76	CHEST	OBL.	24-30	86
L. SPINE	LAT.	27-30	86	RIBS	A.P.	21-24	76
T. SPINE	A.P.	21-24	76	RIBS	A.P.	18-22	70
T. SPINE	OBL.	24-29	80	PREGNANCY	A.P.	Avg.	100
T. SPINE	LAT.	30-34	80	PREGNANCY	LAT.	34-38	100

FIGURE 64.

If a method of technique, employing variable kilovoltage, is to be developed, this procedure may be followed. A model part in four major body areas is radiographed, using some available milliamperage and reasonable time of exposure to arrive at a mas total, with kilovoltage which is found to produce proper density for a given size part. Model parts in the four major body areas are: P.A. Wrist for all extremities; P.A. Chest for all views of the chest; Lateral Skull for all parts of the skull; A.P. Pelvis for all views of the spine, pelvis, abdomen. To establish a set of exposure factors for the extremities, take a P.A. view of a wrist measuring five centimeters. With screens, one and one-quarter mas. is reasonable, and the kilovoltage range for extremities will extend between 45 and 100. There will be extremities smaller and larger than five centimeters, so the tech-

nique to be established should be at a kilovoltage which will permit variation for smaller and larger extremities than the model part. Make three exposures, one at some kilovoltage within the range, one with two kilovolts less and the final exposure with two kilovolts more. Develop the film according to an accepted method and when dry, inspect it for density. One of the three kilovoltage values should be about right. If the film density is not acceptable on any of the three trial exposures, make another test exposure with an appropriate increase or decrease of kilovoltage. Assuming that a test exposure using fifty-four kilovolts at one and one-quarter mas produces a satisfactory radiograph, then the extremity technique chart could be set up in this manner.

CM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	} 1¼ mas.
KVP	46	48	50	52	54	56	58	60	62	64	66	68	70	72	}

The same procedure is followed to establish exposure factors on the model parts in other body areas after decisions have been made concerning the seven variables, mentioned previously.

If this method of technique is to be established, it is well to settle upon a minimum and maximum kilovoltage to be used in each area of the body. The following values may be established:

Extremities	**45 kvp - 100 kvp**
Skull	**60 kvp - 100 kvp**
Sinuses	**56 kvp - 80 kvp**
Mastoids	**60 kvp - 72 kvp**
Jaw	**60 kvp - 75 kvp**
Pelvis	**60 kvp - 80 kvp**
A.P. Lumbar Spine	**60 kvp - 100 kvp**
Lat. Lumbar Spine	**66 kvp - 100 kvp**
A.P. Thoracic Spine	**70 kvp - 100 kvp**
Lat. Thoracic Spine	**65 kvp - 95 kvp**
A.P. Cervical Spine	**60 kvp - 75 kvp**
Lat. Cervical Spine	**60 kvp - 75 kvp**
P.A. Chest	**60 kvp - 100 kvp**
Lat. Chest	**70 kvp - 100 kvp**
Oblique Chest	**60 kvp - 100 kvp**
Abdomen	**65 kvp - 100 kvp**
G.I. Tract	**60 kvp - 100 kvp**
Pregnancy	**70 kvp - 100 kvp**

FIGURE 65.

Milliampere-seconds should be selected so that a small body part will not require less than the minimum and a large part more than the maximum kilovoltages in the range for a given body part.

ETHICAL TIPS IN RADIOGRAPHIC PRACTICE

Establishing technical factors is only one small part of completing an x-ray examination. Every department and every individual either has or develops a system designed to expedite the handling of patients in the department. Whatever the system is, the technician is an important part of that system, and a large part of any successful x-ray examination depends on actions and attitudes not concerned with the immediate production of a radiograph. For instance:

Meet the patient as though you are glad to see him. He is either sick or thinks he is sick. He is human, you know, not a file number.

Be in command of the situation. Act as though you know more about performing your part in this examination than anybody else. The patient is quick to sense that you either do not know what to do or how to do it efficiently.

Take a few seconds to explain to the patient what the examination encompasses and the part he is expected to take in it. Give clear, intelligent, intelligible instructions.

Do not put a patient on the x-ray table or into any uncomfortable position until all preliminary moves are complete and you are ready to make an exposure. Even if the patient is stronger and in better physical condition than you are, assist him on and off the x-ray table. Give him clear, intelligible instructions as to whether he is to dress and wait or wait to dress and where he should wait.

Time is valuable to everyone, including the patient, so do not allow him to wait longer than necessary to be cared for and discharged.

Send him away with the thought that should he ever need the services of a competent x-ray staff again, he will want to be referred to your department.

Whatever you find out about the patient's condition or anything else relating to his visit in your department, forget it. Take care of the next patient.

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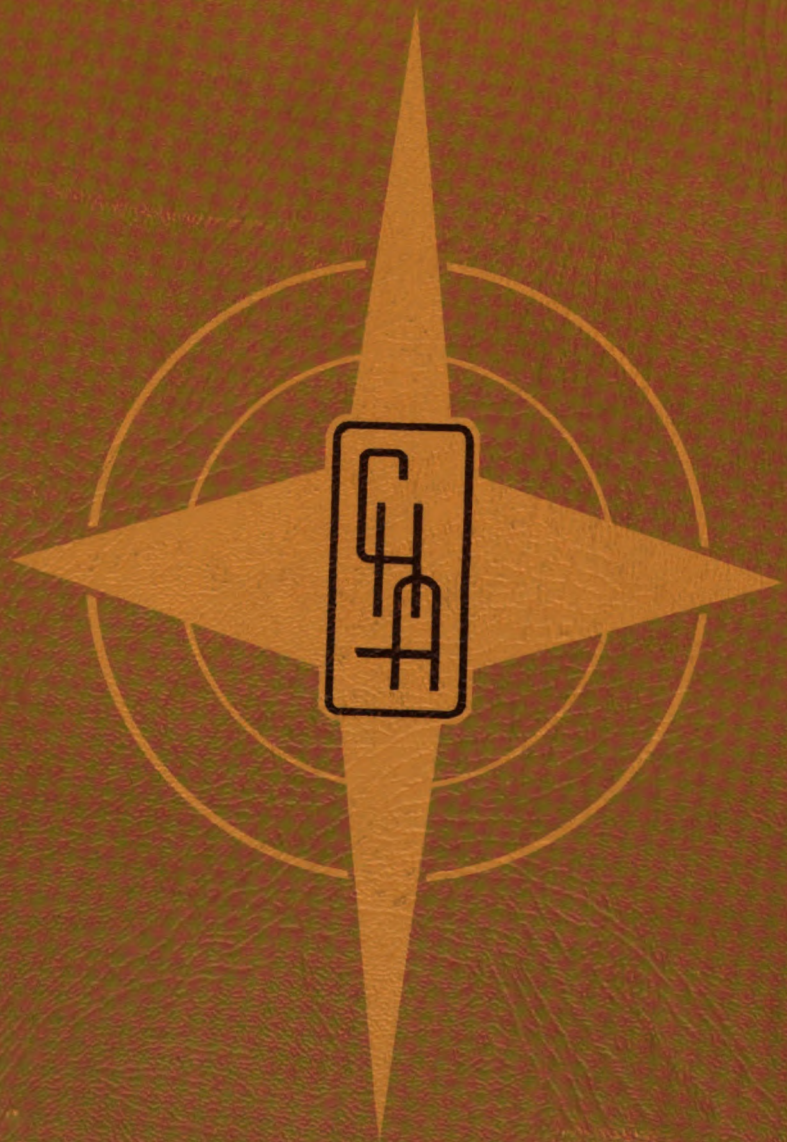
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